



FINAL REPORT

DECONTAMINATION OF EXPLOSIVES- CONTAMINATED RANGE SCRAP USING A TRANSPORTABLE HOT GAS DECONTAMINATION SYSTEM

**U.S. Army Environmental Center
U.S. Army Aberdeen Test Center
Parsons Corporation**

May 2003



Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE MAY 2003		2. REPORT TYPE		3. DATES COVERED 00-00-2003 to 00-00-2003	
4. TITLE AND SUBTITLE Decontamination of Explosives-Contaminated Range Scrap Using a Transportable Hot Gas Decontamination System				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Environmental Center, 5179 Hoadley Road, Aberdeen Proving Ground, MD, 21010-5401				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 182	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

FINALREPORT

**DECONTAMINATION OF
EXPLOSIVES-CONTAMINATED RANGE SCRAP
USING
A TRANSPORTABLE HOT GAS
DECONTAMINATION SYSTEM**

**U.S. Army Environmental Center
U.S. Army Aberdeen Test Center
Parsons Corporation**

May 2003

FINAL

TABLE OF CONTENTS

	Page
1.0 INTRODUCTION	1-1
1.1 Background	1-1
1.2 Objective of the Demonstration	1-2
1.3 Regulatory Issues	1-2
1.4 DoD Policy Issues	1-3
1.5 Safety Issues	1-4
1.6 Previous Testing of the Technology	1-5
2.0 TECHNOLOGY DESCRIPTION	2-1
2.1 Description	2-1
2.1.1 Design Criteria and Details	2-3
2.2 Strengths, Advantages and Weaknesses	2-8
2.2.1 Strengths and Advantages	2-8
2.2.2 Limitations or Weaknesses of HGD	2-8
2.3 Factors Influencing Cost and Performance	2-10
3.0 SITE/FACILITY DESCRIPTION	3-1
3.1 Background	3-1
3.2 Site/Facility Characteristics	3-1
4.0 DEMONSTRATION DESIGN	4-1
4.1 Performance Objectives	4-1
4.2 Physical Set-Up and Operation	4-1
4.2.1 Test Setup	4-1
4.2.2 Test Operation	4-11
4.3 Sampling and Analysis Procedures	4-17
4.3.1 Spiked Coupons	4-17
4.3.2 Emissions Monitoring	4-19
4.4 Pre-Test Background Soil Samples	4-32
5.0 PERFORMANCE ASSESSMENT	5-1
5.1 Burner and Equipment Performance Data and Assessment	5-1
5.1.1 Test 1 Performance Data and Assessment	5-2
5.1.2 Test 2 Performance Data and Assessment	5-6
5.1.3 Test 3 Performance Data and Assessment	5-13

FINAL

TABLE OF CONTENTS (Continued)

	Page
5.1.4 Test 4 Performance Data and Assessment	5-19
5.1.5 Test 5 Performance Data and Assessment	5-25
5.1.6 Test 6 Performance Data and Assessment	5-31
5.1.7 Test 7 Performance Data and Assessment	5-38
5.2 Spiked Coupons	5-44
5.3 Emissions Results	5-60
5.4 Pre-Test Background Soil Samples and Range Scrap	5-86
5.4.1 Background Soil Samples	5-86
5.4.2 Range Scrap	5-88
5.5 Health Hazard Assessment - Handling of Insulation Blanket	5-90
5.5.1 Heath Hazard Data	5-90
5.5.2 Data Assessment and Recommendations for Personal Protective Equipment	5-92
5.6 HGD System Performance Assessment	5-92
5.7 Technology Comparison	5-96
6.0 COST ASSESSMENT	6-1
6.1 Expected Operational Cost	6-1
6.1.1 Cost Data from Demonstration Test	6-1
6.1.2 Operational Cost	6-5
6.2 Cost Comparison	6-9
7.0 REGULATORY ISSUES	7-1
7.1 Approach to Regulatory and End-User Acceptance	7-1
8.0 TECHNOLOGY IMPLEMENTATION	8-1
8.1 DoD Needs	8-1
8.2 Transition Plan	8-3
8.2.1 User Information Campaign	8-3
8.2.2 Summary of Potential System Improvements and Opportunities for Future Testing and Development	8-4
8.2.3 Complete Transportable Demilitarization System	8-5
9.0 LESSONS LEARNED	9-1
9.1 General	9-1
9.2 Equipment and Materials	9-1
9.2.1 Burner System	9-1
9.2.2 Control and Data Acquisition System	9-2
9.2.3 Insulation Materials and Installation	9-2
9.2.4 Utilities	9-4

FINAL

TABLE OF CONTENTS (Continued)

9.3	Security	Page 9-4
10.	REFERENCES	10-1

APPENDICES

A - Points of Contact

B1 - Final Test Plan - Decontamination of Explosives - Contaminated Range Scrap Using A Transportable Hot Gas Decontamination System

B2 - CHPPM Report Ambient Air Quality Assessment

LIST OF TABLES

No.	Title	Page
4.1-1	Performance Objectives	4-1
4.2-1	Pile 1 Contents.....	4-9
4.3-1	Sampling and Analysis Methodology for HGD	4-21
4.3-2	Inorganic Gases (Continuous Emissions Monitoring) Target Analyte List	4-29
4.3-3	TO-14 VOCs Extended Target Analyte List.....	4-30
4.3-4	TO-13 PAHS Target Analyte List.....	4-31
4.3-5	Energetics and Explosives Target Analyte List	4-31
4.3-6	Metals Target Analyte List.....	4-31
4.3-7	SVOCS (8270 List)Target Analyte List.....	4-32
4.4-1	Metals Analytes in Soil	4-33
5.1-1	Time and Temperature Data Summary – Test 1.	5-5
5.1-2	Thermocouple Time to 600°F.....	5-5
5.1-3	Time and Temperature Data Summary – Test #2	5-9
5.1-4	Thermocouple Time to 500°F.....	5-10
5.1-5	Time and Temperature Data Summary – Test 3	5-16
5.1-6	Thermocouple Time to 500°F.....	5-16
5.1-7	Time and Temperature Data Summary – Test 4	5-22
5.1-8	Thermocouple Time to 500°F.....	5-22
5.1-9	Time and Temperature Data Summary – Test #5	5-28
5.1-10	Thermocouple Time to 600 °F.....	5-28
5.1-11	Time and Temperature Data Summary – Test 6	5-34
5.1-12	Thermocouple Time to 500°F.....	5-35
5.1-13	Time and Temperature Summary – Test 7	5-40
5.1-14	Thermocouple Time to 500 °F.....	5-41
5.2-1	Hot Gas Decontamination Results for Test 1	5-45
5.2-2	Hot Gas Decontamination Results for Test 2	5-47
5.2-3	Hot Gas Decontamination Results for Test 3°	5-49
5.2-4	Hot Gas Decontamination Results for Test 3°	5-50

FINAL

TABLE OF CONTENTS (Continued)

LIST OF TABLES (Continued)

No.	Title	Page
5.2-10	Explosive Detection On Range Scrap	5-58
5.2-5	Hot Gas Decontamination Results for Test 3 ^c	5-51
5.2-6	Hot Gas Decontamination Results for Test 4	5-53
5.2-7	Hot Gas Decontamination Results for Test 5	5-54
5.2-8	Hot Gas Decontamination Results for Test 6	5-55
5.2-9	Hot Gas Decontamination Results for Test 7	5-56
5.2-11	Explosives Detected On Scrap	5-59
5.2-12	Explosive Detection On Range Scrap	5-60
5.3-1	Inorganic Gas Concentrations Summary	5-61
5.3-2	Volatile Organic Compound Concentrations Summary	5-72
5.3-3	Polycyclic Aromatic Hydrocarbons Concentrations Summary	5-74
5.3-4	Semi-Volatile Organic Compound Concentrations Summary	5-77
5.3-5	Energetic and Explosive Compound Concentrations Summary	5-82
5.3-6	Metal Concentrations Summary	5-83
5.3-7	Particulate Concentrations Summary	5-85
5.3-8	Summary of Samples Which Exceeded the Standard.	5-86
5.4-1	Metals Results & Average For Before Test Soil Samples	5-87
5.4-2	Explosives Results For Before Test Soil Samples	5-88
5.4-3	Explosive Detection On Range Scrap	5-88
5.4-4	Explosives Detected On Scrap	5-89
5.4-5	Explosives Detected In Dumpster Water	5-89
5.5-1	Industrial Hygiene Air Sampling Results	5-91
5.6-1	Performance Objectives And Assessment	5-93
5.6-2	Test-Specific Objectives And Assessment	5-94
5.7-1	Technology Comparison	5-97
6.1-1	Miscellaneous Maintenance Parts Used in Demonstration Test.	6-2
6.1.2	Insulation Used in Demonstration Test.	6-2
6.1-3	HGD Total Square Footage and Cost Per Trial	6-3
6.1-4	HGD Average Cost Over Seven Tests.	6-4
6.1-5	Cost Summary for Demonstration Test	6-5
6.1-6	Mobilization Cost Breakdown	6-6
6.1-8	Operational HGD Insulation and Wire Materials Quantities and Associated Costs	6-7
6.1-9	Startup Operations Cost Estimate	6-8
6.1-10	Full-Scale Production Cost Estimate	6-9
6.2-1	Technology Comparison - 15,000 Ton Site Cost Comparison	6-10

FINAL

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

No.	Title	Page
1.1-1	Range Scrap at ATC.....	1-2
2.1-1	Transportable Hot Gas Decontamination System and Insulation Blanket	2-2
2.1-2	Process Schematic	2-2
2.1-3	Burner Assembly and Skid.....	2-4
2.1-2	Burner Control Panel.....	2-6
3.1-1	Air Base Range 9.....	3-2
3.1-2	Air Base Range 9 RoA Soil Type	3-2
4.2-1	Skid Mounted 2.5 Million Btu Propane Burner And Control System.	4-2
4.2-2	A Remote Personal Computer Based Operator Workstation.	4-3
4.2-3	A 30-Kilowatt Diesel Powered Generator and 500 Gallon Auxiliary Tank.....	4-3
4.2-4	Two 1000-Gallon Propane Fuel Tanks.	4-4
4.2-5	K - Type Thermocouple and Plate	4-4
4.2-6	Wire Mesh, Thermal Blankets and Chicken Wire.	4-5
4.2-7	Inside and Outside Views of Spiked Coupon Box.....	4-5
4.2-8	Range Light and Camera 4.2-9 – Range Shield for Data Trailer	4-6
4.2-10	One of Four Sets of Ambient Air Emissions Monitors (From Left to Right - Volatile Organic Compounds (VOC's), Explosives, Particulate Matter less than 2.5 Microns (PM 2.5), Particulate Matter less than 10 Microns (PM 10), Total Suspended Particulate Matter (TSP), Polycyclic Aromatic Hydrocarbons / Semi-Volatile Organic Compounds (PAH/SVOC's)).	4-6
4.2-13	Range Completely Set-up for Testing.....	4-7
4.2-14	Test Setup at ABR-9.....	4-8
4.2-15	Dumpsters and Wooden Boxes Used To Store Inspected Range Scrap.....	4-9
4.2-16	Typical Arrangement – Thermocouple Location in Pile.....	4-16
4.3-1	Inside and Outside Views of Spiked Coupon Box	4-17
4.3-2	Location of Emission Samplers in comparison to Range Scrap Pile	4-20
4.3-3	Samplers Located in Front of the Burner (Front Site).....	4-20
4.3-4	Samplers Located Left of the Burner (Left Site).....	4-20
4.3-5	Samplers Located Right of the Burner (Right Site).	4-21
4.3-6	Samplers Located Above the Burner (Top Site).	4-21
5.1-1	Thermocouple Location for Test Pile #1.....	5-3
5.1-2	After Test 1 Blanket Conditions.....	5-4
5.1-3	Test 1 Heatup Time vs. Temperature	5-6
5.1-4	Thermocouple.....	5-7
5.1-6	Test 2 System Heatup Performance – Elapsed Time vs. Temperature	5-11
5.1-7	Test 2 Heatup Time Vs. Temperature for Hottest and Coolest Locations	5-12

FINAL

TABLE OF CONTENTS (Continued)

LIST OF FIGURES (Continued)

No.	Title	Page
5.1-8	Temperature Distribution versus Distance from Burner – Top of Pile	5-12
5.1-9	Temperature Distribution versus Distance from Burner – Bottom Perimeter of Pile.....	5-13
5.1-10	Brittle Insulation.....	5-14
5.1-11	Thermocouple Location for Test 3.....	5-15
5.1-12	Test 3 System Heatup Performance – Elapsed Time vs. Temperature	5-18
5.1-13	Test 3 Heatup Time Vs. Temperature for Hottest and Coolest Locations	5-18
5.1-14	Test 3 Temperature Distribution versus Distance from Burner – Top of Pile.....	5-19
5.1-15	Test 3 Temperature Distribution versus Distance from Burner – Bottom Perimeter of Pile.....	5-19
5.1-16	Thermocouple Location of Test Pile #4.....	5-21
5.1-17	Test 4 System Heatup Performance – Elapsed Time vs. Temperature	5-24
5.1-18	Test 4 Heatup Time Vs. Temperature for Hottest and Coolest Locations	5-24
5.1-19	Test 4 Temperature Distribution versus Distance from Burner – Top of Pile.....	5-24
5.1-20	Test 4 Temperature Distribution versus Distance from Burner – Bottom Perimeter of Pile.....	5-25
5.1-21	Thermocouple Locations for Test #5	5-27
5.1-22	Test 5 System Heatup Performance – Elapsed Time vs. Temperature	5-29
5.1-23	Test 5 Heatup Time Vs. Temperature for Hottest and Coolest Locations	5-30
5.1-24	Test 5 Temperature Distribution versus Distance from Burner – Top of Pile.....	5-30
5.1-25	Test 5 Temperature Distribution versus Distance from Burner – Bottom Perimeter of Pile.....	5-31
5.1-26	Thermocouple Locations for Test 6	5-33
5.1-27	Test 6 System Heatup Performance – Elapsed Time vs. Temperature	5-36
5.1-28	Test 6 Heatup Time Vs. Temperature for Hottest and Coolest Locations	5-36
5.1-29	Test 6 Temperature Distribution versus Distance from Burner – Top of Pile.....	5-37
5.1-30	Test 6 Temperature Distribution versus Distance from Burner – Bottom Perimeter of Pile.....	5-37
5.1-31	Thermocouple Location for Test 7.....	5-39
5.1-32	Test 7 System Heatup Performance – Elapsed Time vs. Temperature	5-42
5.1-33	Test 7 Heatup Time Vs. Temperature for Hottest and Coolest Locations	5-42
5.1-34	Test 7 Temperature Distribution versus Distance from Burner – Top of Pile.....	5-43
5.1-35	Test 7 Temperature Distribution versus Distance from Burner	5-43
5.2-1	Hot Gas Decontamination Spiked Coupons Locations for Test 1.....	5-44

FINAL

TABLE OF CONTENTS (Continued)

LIST OF FIGURES (Continued)

No.	Title	Page
5.2-2	Spiked Coupons Locations for Test 2	5-46
5.2-3	Spiked Coupons Locations for Test 3 ^c	5-48
5.1-4	Spiked Coupons Locations for Test 3 ^c	5-50
5.2-5	Spiked Coupons Locations for Test 3 ^c	5-51
5.2-6	Hot Gas Decontamination Spiked Coupons Locations for Test 4.....	5-52
5.2-7	Hot Gas Decontamination Spiked Coupons Locations for Test 5.....	5-54
5.2-8	Spiked Coupons Locations for Test 6	5-55
5.2-9	Hot Gas Decontamination Spiked Coupons Locations for Test 7.....	5-56
5.3-1	Test 1 CO Concentration vs Time	5-62
5.3-2	Test 1 CO Concentration vs Time for 1 to 5 hours	5-62
5.3-3	Test 1 CO ₂ Concentration vs Time.....	5-63
5.3-4	Test 1 CO ₂ Concentration vs Time for 1 to 5 hours.....	5-63
5.3-5	Test 1 NO _x Concentration vs Time	5-64
5.3-6	Test 1 NO _x Concentration vs Time for 1 to 5 hours.....	5-64
5.3-7	Test 2 CO Concentration vs Time	5-65
5.3-8	Test 2 CO Concentration vs Time for 0 to 3 hours	5-65
5.3-9	Test 2 CO ₂ (1-1000 ppm) Concentration vs Time	5-66
5.3-10	Test 2 CO ₂ (1-5000 ppm) Concentration vs Time	5-66
5.3-11	Test 2 NO _x Concentration vs Time	5-67
5.3-12	Test 2 NO _x Concentration vs Time for 21 to 21.5 hours.....	5-67
5.3-13	Test 6 SO ₂ Concentration vs Time	5-68
5.3-14	Test 6 SO ₂ Concentration vs Time for 0 to 1 hour.....	5-68
5.3-15	Test 6 CO Concentration vs Time on 16 October 2001	5-69
5.3-16	Test 6 CO Concentration vs Time for 0 to 3 hours	5-69
5.3-17	Test 6 CO ₂ (0-1000ppm) Concentration vs Time	5-70
5.3-18	Test 6 CO ₂ (0-5000ppm) Concentration vs Time	5-70
5.3-19	Test 6 NO _x Concentration vs Time	5-71

FINAL

List of Acronyms

AAP	Army Ammunition Plant
ABR-9	Air Base Range 9
AD-3	Ammunition Dump 3
AEC	Army Environmental Center
AEDA	Ammunition, Explosives, and Dangerous Articles
APG	Aberdeen Proving Ground
ATC	Aberdeen Testing Center
ATIRS	Automated Test Incident Reporting System
BCS	burner control system
BRAC	Base Realignment and Closure
BRACO	BRAC Office
CAA	Clean Air Act
CCTV	closed circuit television
CEM	continuous emissions monitor
C&P	Cost and Performance
COTS	commercial off-the-shelf
CRREL	Cold Regions Research and Engineering Laboratory
CTT	Closed, Transferred, and Transferring
DoD	Department of Defense
DRMO	Defense Reutilization and Marketing Office
DSHE	Directorate of Safety, Health, and Environment
ECP	Explosives Contaminated Property
ECAM	Environmental Cost Analysis Method
ESTCP	Environmental Security Technology Certification Program
FUDS	Formerly Used Defense Sites
IDL	Instrument Detection Limit
IG	Inspector General
GC/MS	gas chromatograph/mass spectrometer
HGD	hot gas decontamination
HMX	Octahydro-1,2,5,7-tetranitro-1,3,5,7-tetrazocine
HQDA	Headquarters Department of the Army
HPLC	high performance liquid chromatography
IDL	instrument detection limit
I/O	input/output
IOC	Industrial Operations Command
IOP	Internal Operating Procedures
IPR	In-Process Reviews
JHA	Job Hazard Analysis
LCS	laboratory control sample
MDE	Maryland Department of Environment
MHE	material handling equipment
MMR	Military Munitions Rule
MPPEH	Material that Presents the Potential for Explosives Hazard

FINAL

MSDS	Material Safety Data Sheets
NAAQS	National Ambient Air Quality Standards
NEMA	National Electric Manufacturers Association
NIST	National Institute of Standards and Technology
NFPA	National Fire Protection Agency
NO _x	oxides of nitrogen
OEESCM	Operational and Environmental Executive Steering Committee
OW	operator workstation
PAHs	polycyclic aromatic hydrocarbon compounds
PETN	Pentaerythritol tetranitrate
PLC	programmable logic controller
PM _{2.5}	particulate matter with an aerodynamic diameter less than or equal to 2.5 microns
PM ₁₀	particulate matter with an aerodynamic diameter less than or equal to 10 microns
PPE	personal protective equipment
QA	quality assurance
QAPP	Quality Assurance Project Plan
R3	Resource Recovery and Recycle
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine
REC	Record of Environmental Consideration
RPD	relative percent difference
SOP	standard operating procedure
SSHSP	Site-Specific Health and Safety Plan
SVOC	Semi-volatile organic compounds
TCLP	Toxic Characteristic Leaching Procedure
TIR	Test Incident Report
TNT	Trinitrotoluene
TSOP	Temporary Standing Operating Procedures
USAEC	U.S. Army Environmental Center
USAGAPG	U.S. Army Garrison Aberdeen Proving Ground
USEPA	U.S. Environmental Protection Agency
UXO	unexploded ordnance
VOC	volatile organic compounds
Yellow D	Ammonium Picrate

FINAL

1.0 INTRODUCTION

This report documents the results of the field demonstration of a transportable hot gas decontamination (HGD) system for decontamination of explosives-contaminated range scrap. Under management of the U.S. Army Environmental Center (USAEC), a low-cost HGD process configuration was selected by the Environmental Security Technology Certification Program (ESTCP) for full-scale demonstration of field decontamination of explosives-contaminated range residue at the U.S. Army Aberdeen Test Center (ATC), located on Aberdeen Proving Ground (APG), Maryland. In addition to funding by ESTCP, additional financing has been provided by the USAEC to perform this field demonstration. This report documents the performance of the decontamination system, provides design and operational details and performance of the materials and equipment, and provides a performance assessment of operational data, including air emissions monitoring and test coupons.

1.1 BACKGROUND

The Department of Defense (DoD) has numerous target, bombing, test, and firing ranges that have accumulated a substantial amount of high-value recyclable scrap metal in the form of ammunition, explosive, and dangerous articles (AEDA), range residue, Explosives-Contaminated Property (ECP), and Materials that Present the Potential for Explosive Hazard (MPPEH). This scrap metal includes practice bombs, expended artillery, small arms and mortar projectiles, aircraft bombs and missiles, rockets and rocket motors, hard targets, grenades, incendiary devices, experimental items, demolition devices, and other materials fired on or upon a military range (See Figure 1.1-1). These articles include various expended primers, flash tubes, stub bases, and other items and present a unique problem to generating activities. This material is collected in range sweeps and removal operations at active and inactive ranges, and unexploded ordnance (UXO) removal operations at Closed, Transferred, and Transferring (CTT) sites. Contrary to popular belief, these items often have explosives residue after detonation. Explosive incidents involving scrap metal from training and firing ranges have occurred over the years and recently have come under close scrutiny.

A safe, environmentally conscious alternative to decontaminate firing range scrap is a low-temperature thermal desorption process called the hot gas decontamination (HGD) technology developed by the U.S. Army Environmental Center (USAEC). The HGD technology uses controlled heat to volatilize and thermally decompose the explosives contamination. A low-cost HGD process configuration was demonstrated in which the scrap metal is placed in piles and covered with an insulated thermal blanket. Propane-fired portable burners inject heat at a controlled rate to meet the time and temperature criteria (up to 600°F for up to a 6-hour holding time), to reach a decontamination level which can be certified as inert. Range residue has not previously been decontaminated in this manner. Although not used on range residue, many Army facilities have flashed range scrap to make it safe for sale before the range residue problem developed. Although this method did not use propane as the heat source, the use of wood or petroleum-based fuel was used to heat-treat metal scrap.

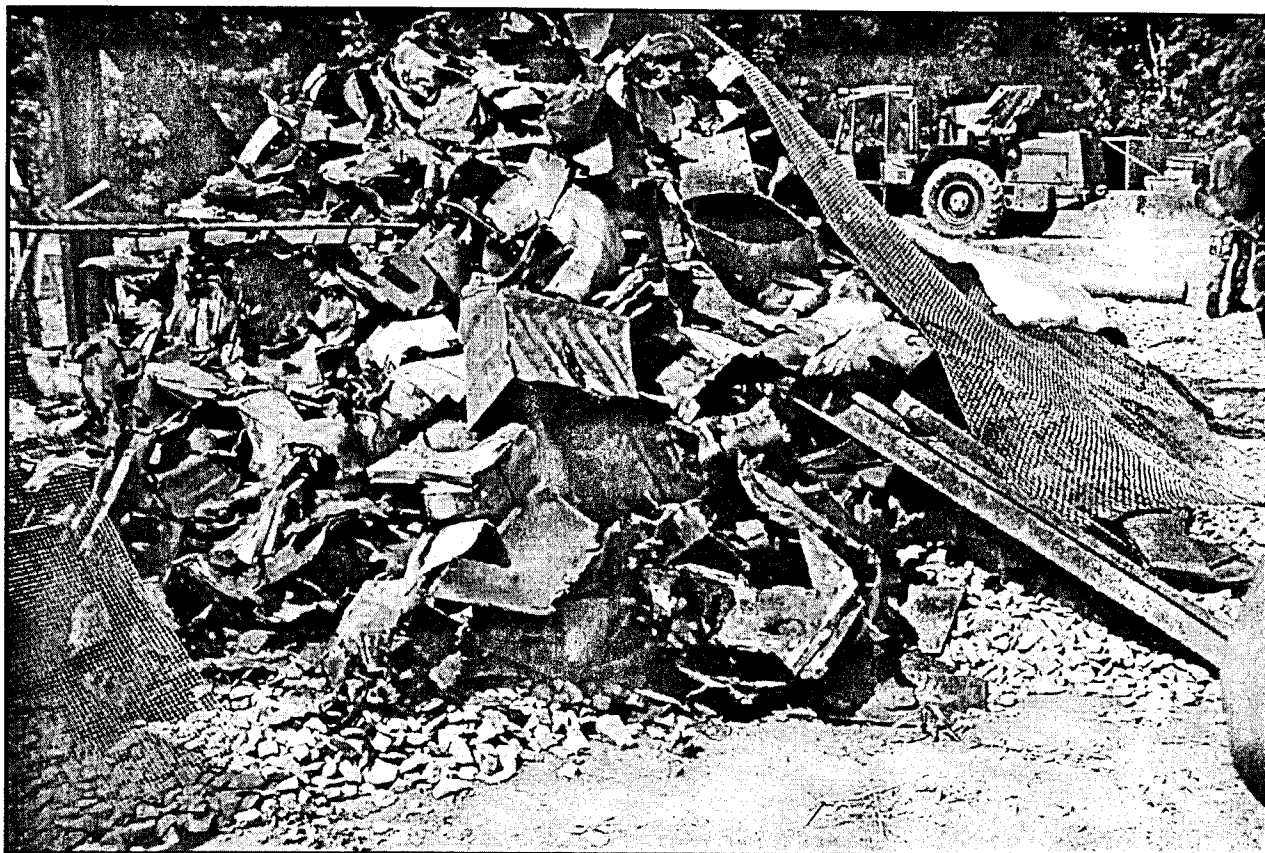


Figure 1.1-1 Range Scrap at ATC

1.2 OBJECTIVE OF THE DEMONSTRATION

The objective of this project is to demonstrate the safe and effective decontamination of range scrap materials at the lowest possible cost. Using commercially available equipment and materials, this project demonstrated an effective, safe, temporary, and portable hot gas system for decontaminating explosives-contaminated range scrap materials. Currently, the high costs associated with establishing and maintaining permanent hot-gas decontamination structures has made the technology unattainable for many installations. This project implements the HGD technology at APG using the design criteria developed by USAEC and Parsons, as detailed in the technical report "Design Guidance Manual for Low Cost Disposable Hot Gas Decontamination System for Explosives-Contaminated Equipment and Facilities," November 1998¹.

1.3 REGULATORY ISSUES

The promulgation of the U.S. Environmental Protection Agency (USEPA) Military Munitions Rule has brought a new focus to the topic of range scrap removal on active, inactive, and Closed, Transferred and Transferring (CTT) ranges.

Range scrap is high value metal and an outstanding resource for recycling. As such, if recycled the range scrap falls into the RCRA exemption for recycling (i.e. it is not a RCRA waste if recycled). These means that that a range scrap demilitarization system should not fall under the RCRA generator rules or the RCRA Treatment, Storage, and Disposal rules.

FINAL

Explosives contamination from range residue potentially can leach into the soil, surface water, and groundwater during rainfall on military firing ranges. Soil erosion around blast holes caused by detonations can accelerate and magnify this effect. Without decontamination of the range residue, the explosive-contaminated scrap has historically been shipped to scrap recyclers, with potential for more spread of explosive contamination on transport trucks and to soil and water at outdoor recyclers' scrap yards.

Previous demonstrations of HGD technology used an off-gas treatment system to treat volatilized emissions. Generally speaking, it is the off-gas treatment system which is very expensive and drives the overall system cost upwards. The off-gas treatment system typically can be 25 to 40 percent of the overall system cost. As a one-time decontamination action, off-gas treatment is not an absolute requirement by regulators at all locations. This was demonstrated by recent (1996) permission by the Oregon Department of Environment Quality² to open burn (flash flame) the Explosives Washout Building at Umatilla Chemical Depot, Umatilla, Oregon without emissions control or treatment. The requirement for an off-gas treatment system must be evaluated on a case-by-case basis considering the site location and distance away from populated areas and off-site receptors, and local and state regulatory standards. Environmental permitting requirements, emissions limitations, and monitoring (continuous or intermittent) requirements will be determined on a case-by-case basis. Use of emissions estimates, air modeling, and fate and transport models may be used to make a case for HGD with no off-gas treatment. Operational controls (such as wind speed and direction restrictions) can be placed on the system to further promote the concept of HGD processing without off-gas treatment. For example, in a remote location with a reasonable regulatory oversight and no nearby receptors, a HGD system with no off-gas treatment may be judged acceptable as a quick, low-cost method to remove contamination.

1.4 DOD POLICY ISSUES

A recent DoD Range Sustainability initiative has placed urgency on maintenance of active and inactive ranges, including detection and removal of ordnance and explosives (and range residue). Also, there is an immediate need for clearance and removal of firing range scrap at Base Realignment and Closure (BRAC) sites and Formerly Used Defense Sites (FUDS) sites, where public use and redevelopment priorities, and other economic issues such as ongoing maintenance, security, and care-taking costs are driving factors. Some ranges from BRAC '88 are still not fully cleaned up, and there is great incentive for DoD to clean up and close these ranges prior to the next round of base closures (preliminarily planned for 2005).

The disposal of range residue has recently been a matter of heightened interest among Congress and DoD officials. Each year, the Services expend more than 200,000 tons of munitions. In the Department of Defense Office of the Inspector General (DoD IG) Audit, "Review of Policies and Procedures Guiding the Cleanup of Ordnance on DoD Lands"³, DoD IG reported that expended ordnance and explosive waste cleanup requirements and guidance developed by DoD and the Military Departments were incomplete, vague, and inconsistent.

Three years later, the Office of the Secretary of Defense requested the Inspector General, DoD, to evaluate the munitions disposal process after a commercial scrap worker was killed by a live anti-tank munitions shell. DoD IG responded with a separate audit entitled "Evaluation of the Disposal of Munitions Items" (Report No. 97-213, September 5, 1997)⁴. The primary objective was to determine whether DoD procedures and controls adequately ensured the safe disposal of

FINAL

ammunition, explosives, and other dangerous articles (AEDA) residue. The audit specifically evaluated the adequacy of the policies, procedures, and management controls associated with the disposal of DoD managed munitions. The audit report contained 25 separate recommended actions and concluded that the DoD needs to improve management controls to prevent public access to live AEDA. Specifically, DoD controls for the disposal of AEDA residue by the Military Departments were ineffective. As a result, the public was sold or had access to either discarded live AEDA or AEDA residue that had not been properly certified as inert. Management controls at the Defense Reutilization Marketing Service to prevent the sale of live AEDA to the public were not fully effective. As a consequence, Defense Reutilization and Marketing Offices received and sold uncertified and improperly certified and stored AEDA residue to the public. DoD policies and procedures for AEDA disposal contracts, Direct Sales Programs as part of the Qualified Recycling Programs, reporting and investigating AEDA incidents, and demilitarization were inadequate. As a result, AEDA disposal service and sales contracts varied by installations and included disparate levels of safety and oversight.

A follow-up audit, "Disposal of Range Residue" (Report No. D-2000-170 August 4, 2000)⁵, revisited the status on the recommended actions of the 1997 audit report by reviewing current operations at eight military installations and their servicing Defense Reutilization and Marketing Offices. To address recommendations in Report No. 97-213, the Under Secretary of Defense for Acquisition, Technology, and Logistics convened a review team. A draft report contained recommendations to improve the disposal process, but did not contain standard DoD-wide guidance for managing the disposal of range residue, as recommended in the 1997 report. In early FY 2000, the Under Secretary directed a far-reaching and comprehensive review of munitions by the Operational and Environmental Executive Steering Committee for Munitions (OEESCM). The objective was to determine whether the Services were disposing range residue in a safe manner. Specifically, the adequacy of the policies, procedures, and management controls associated with the disposal of range residue generated on DoD terrestrial firing ranges. DoD IG recommended that the Under Secretary of Defense for Acquisition, Technology, and Logistics have the OEESCM address the policy and procedural weaknesses and develop implementing guidance. As a result of the findings of the DoD IG audit, the Office of Deputy Under-Secretary of Defense for Installations and Environment is currently preparing an instruction for handling and disposition of Material that Presents a Potential for Explosives Hazards (MPPEH). A draft DoD instruction for handling and disposal of MPPEH is under preparation by an OEESCM subcommittee and planned for issue in 2002.

1.5 SAFETY ISSUES

The uncertainties associated with certification by visual inspection present unacceptable risk to human health for inspectors, range personnel removing scrap, and to transporters and commercial recyclers. In the past several years, explosive incidents involving scrap metal from firing ranges have occurred during handling operations, resulting in death or serious injuries, and forcing the DoD to review current scrap metal disposal practices. The advantage of remote operation of the HGD system as demonstrated lowers risk to range workers in the event of explosive incident, and eliminates off-site risk to the general public, including commercial recyclers.

FINAL

1.6 PREVIOUS TESTING OF THE TECHNOLOGY

The HGD technology is well developed and supported by considerable research and demonstration. The USAEC began conducting bench-scale studies in the late 1970s to evaluate HGD technology for treatment of equipment, piping, metallic debris, and building materials contaminated with both explosive materials and chemical warfare agents. Successful pilot studies were followed by demonstration testing to define and refine the performance parameters. HGD technology is now available for field implementation and treatment of installations contaminated with explosive materials or chemical warfare agents.

HGD technology was developed and demonstrated as follows:

- In 1987, a pilot-scale study⁶ for HGD technology using samples spiked with chemical warfare agent was conducted at Dugway Proving Ground, Utah. This controlled study successfully demonstrated the ability of the HGD technology to decontaminate agent from concrete and steel.
- Based on these results, pilot-scale tests⁷ using the HGD technology to treat contamination with explosive materials were conducted at the Cornhusker Army Ammunition Plant in 1989. The Cornhusker test results indicated that the HGD technology seemed to be effective, but more studies were needed for application to explosive materials.
- Successful pilot-scale tests⁸ were conducted in 1990 at Hawthorne Army Ammunition Plant for equipment, piping, and metal debris, including shell casings, contaminated with explosive materials. These studies defined HGD parameters for treatment of materials contaminated with explosive materials.
- Additional demonstration studies⁹ were conducted in 1994 at Hawthorne for explosives contained within munitions, such as ship mines, depth bombs, and 106-mm and 5-inch projectiles. These latter Hawthorne results were successful, but indicated that equipment optimization should be further explored for explosive munitions applications.
- In 1994, a field demonstration¹⁰ of HGD technology for facility and process equipment was successful in treating chemical warfare agent contamination at the Rocky Mountain Arsenal. This field demonstration provided HGD performance parameters for decontamination of former chemical agent installations.
- In 1995, validation testing for optimization of equipment using HGD technology for treatment of piping and debris contaminated with explosive material was conducted at the Alabama Army Ammunition Plant^{11,12}. This validation testing provides HGD performance parameters for decontamination of former explosive materials installations.

Previous demonstrations of the technology have proven it effective both *in situ* (Cornhusker, Nebraska and Rocky Mountain Arsenal, Colorado) and *ex situ* by placing dismantled equipment and scrap metal in a furnace (Hawthorne, Nevada and Alabama Army Ammunition Plant, Alabama). The Hot Gas Decontamination technology has been proven effective in decontaminating explosives contamination for the following types of explosive materials:

- 2,4,6-Trinitrotoluene (TNT),
- Ammonium picrate (Yellow D),
- Royal Demolition Explosives or Research Department Explosives (RDX),
- Composition A-3 (RDX and wax),

FINAL

- Composition B (TNT, RDX and wax),
- Tetryl,
- Smokeless Powder (Nitrocellulose/Nitroglycerin), and
- HBX (TNT, RDX, aluminum, lecithin, and wax).

2.0 TECHNOLOGY DESCRIPTION

2.1 DESCRIPTION

The HGD technology was developed by the U.S. Army Environmental Center (USAEC), Aberdeen Proving Ground, Maryland as an environmentally safe alternative to decontaminate equipment (scrap metal) and buildings contaminated with explosives or chemical agents. The HGD process uses low temperature heat (500 to 600°F) to volatilize and decompose explosives residues in contaminated range scrap metal. Hot burner gas directly contacts the contaminated materials to elevate its temperature. The effectiveness of the process is both time and temperature dependent. Holding times between 1 and 6 hours have been shown to be effective at the prescribed soak temperature. Volatilization is the primary decontamination mechanism, but some in-place decomposition also takes place. Because of the type and character of the constituents of the off-gas, at some sites it may be necessary to contain, collect, and further treat the gaseous discharge to meet environmental regulatory stipulations.

The HGD System demonstrated in this test is a gas-fired burner system heating a pile of explosives-contaminated range residue covered by an insulation blanket as shown in Figure 2.1-1. The HGD system requires a heat source, thermal insulation and supports, a thermocouple array, a data acquisition system, a power supply, and a basic control system. This system can provide a heat-soak to the target contaminated area at a temperature of 500 to 600°F. This is inherently a low-cost method to decontaminate piles of explosives-contaminated scrap metal.

This configuration of the HGD system is applicable to piles of range scrap that are typical in size that may be found or that may be readily constructed on active ranges. A process schematic of the HGD system in the pile configuration as demonstrated is shown in Figure 2.1-2. An air heater is used to heat the pile of range residue. A standard air heater fueled by propane was used for process heating. To minimize heat losses and maintain heat in the scrap pile, fire-resistant thermal fabric and insulation is draped over equipment and pipe to contain the hot air. The thermal blanket is supported and held down by welded wire mesh to protect it from damage or displacement by wind.

Emissions from the HGD process vent around the edges of the thermal blanket at the base of the pile, through seams in the thermal blanket, and permeate through the blanket fabric. An extensive network of continuous air monitors was used to monitor the ambient air quality in the vicinity of the pile during demonstration test operations.

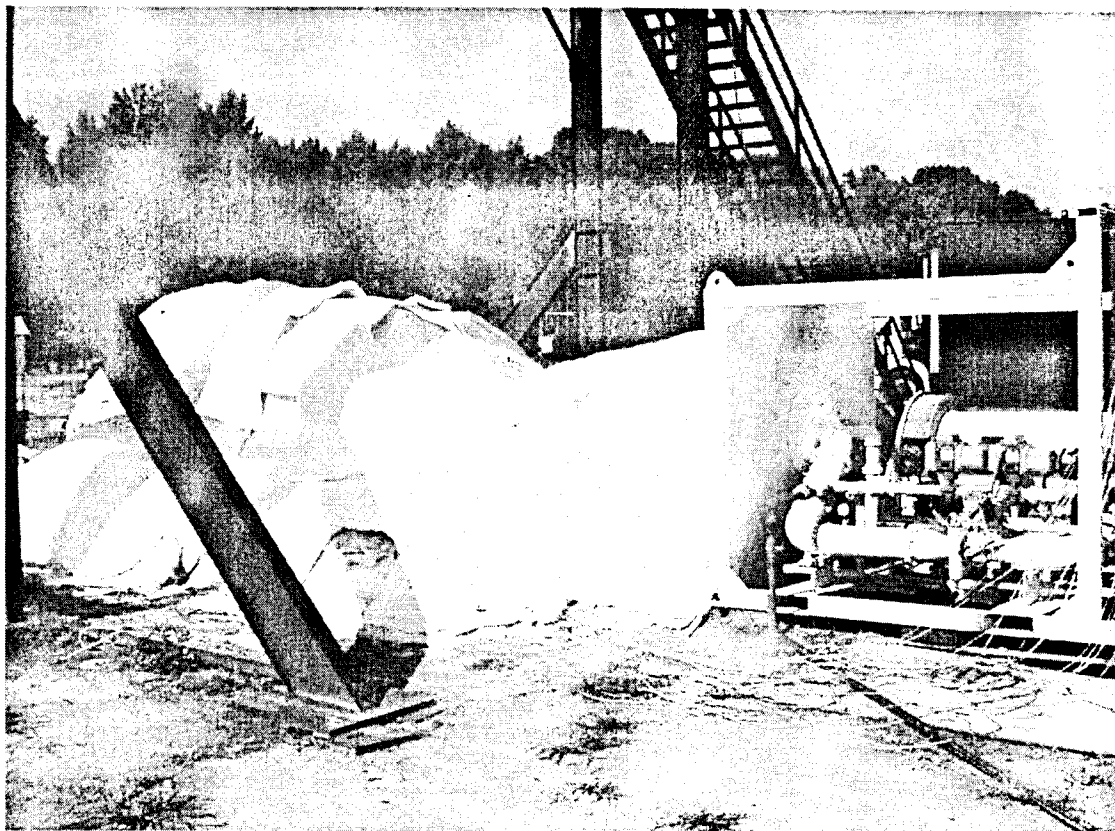


Figure 2.1-1 – Transportable Hot Gas Decontamination System and Insulation Blanket

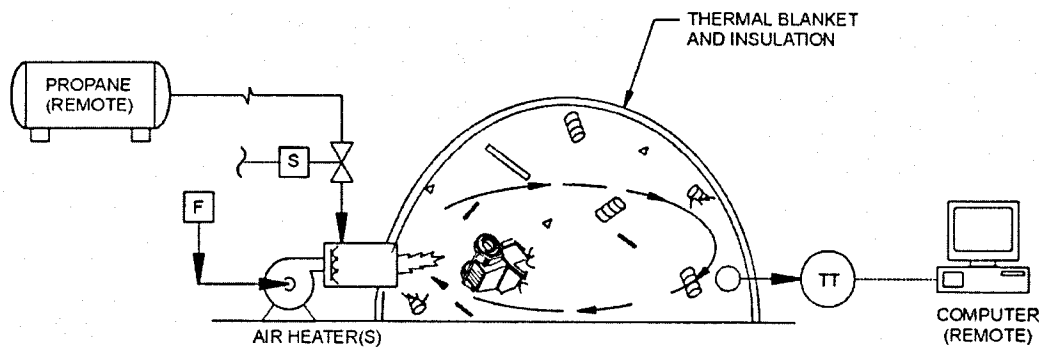


FIGURE 1
LOW COST HOT GAS
DECONTAMINATION SYSTEM
FOR FIRING RANGE SCRAP
(NO OFF-GAS TREATMENT)

Figure 2.1-2 Process Schematic

Thermocouples with temperature transmitters are interlocked to the air heater fuel supply to control the programmed soak temperature of the scrap metal in the pile. The thermocouples are

FINAL

strategically placed at expected cooler locations (near the outside of the pile away from the burners). During heat up, the thermocouples indicate when their location has met the specified temperature criteria, and the heat soak can commence. When all of the thermocouples reach the soak temperature for the specified time, the decontamination process is complete.

The thermocouple signals are transmitted to a remote control station for recording and decision-making. Twelve thermocouples were used for the demonstration. A simple control process is employed for ease of operation and installation. Instrumentation is configured for remote read-out, with local read-out being used only for set up and test. Electrical power is provided by a leased diesel generator and fuel tank.

2.1.1 Design Criteria and Details

FUNCTIONAL DESIGN REQUIREMENTS

Based on the knowledge and experience gained from the field demonstrations, the following functional requirements ensure the cost-effective implementation of the HGD process:

- The system effectively meets decontamination requirements while ensuring the health and safety of workers and the general public, and protection of the environment;
- Regulatory agency approval and required permits are obtained. Ambient air monitoring is conducted as required to meet regulatory requirements. Monitoring requirements are developed on a case-by-case basis as required by the local regulatory agency;
- The system uses locally available stock items, standard equipment, and expendables and standard disposable materials of construction to minimize cost;
- Use of leased and/or disposable equipment for one-time use and short project life;
- Applicable to range residue that is free from live munitions; and
- Labor and utility requirements are minimized as much as possible.

PERFORMANCE CRITERIA

Previous demonstrations of the HGD technology explored the temperature-time relationship necessary for achieving 5X-equivalent decontamination of explosives-contaminated equipment and facilities. In accordance with Headquarters Department of the Army Technical Bulletin 700-4¹⁴ "5X (XXXXX) level of contamination indicate that facilities and equipment have been completely decontaminated, are free of hazard, and may be released for general use or the general public", for facilities and equipment exposed to potential ammunition, explosives and explosives residue contamination. The HGD technology process utilizes low-temperature heat to decontaminate scrap metal that are contaminated with explosives. Under the heated conditions, the explosives residues in the material are volatilized or thermally degraded in place. Decontamination of the scrap metal is accomplished by maintaining the soak temperature over the specified time period required to meet the decontamination levels.

Results from tests at Hawthorne Army Depot⁹ indicate a temperature between 550°F and 600°F for a six-hour soak was required. Test results from Alabama Army Ammunition Plant^{11,12} indicate the optimum operating conditions for achieving complete destruction of TNT, RDX, tetryl, and their breakdown constituents (i.e., to levels below method detection limits) were 600°F with a one-hour soak. The current project further established time and temperature performance criteria that are reported in Section 5, Performance Assessment, of this report.

BURNER AND FUEL SYSTEM

The burner system is a skid-mounted assembly complete with combustion air fan, control panel, and burner shroud to direct the heat into the pile, as shown in Figure 2.1-3. The burner is placed adjacent to the pile but not directly contacting the pile (or in the pile). Hot burner gas is directed into the pile through the shroud. High temperature thermal insulation is draped around the burner shroud and onto the scrap pile to provide a seal around the burner interface with the scrap pile. The insulation is supporting by stainless steel wire mesh that stretches from the burner shroud to the pile and down to the ground. The burner interface is configured such that the burner flame is not permitted to contact the scrap from the pile or the insulation.

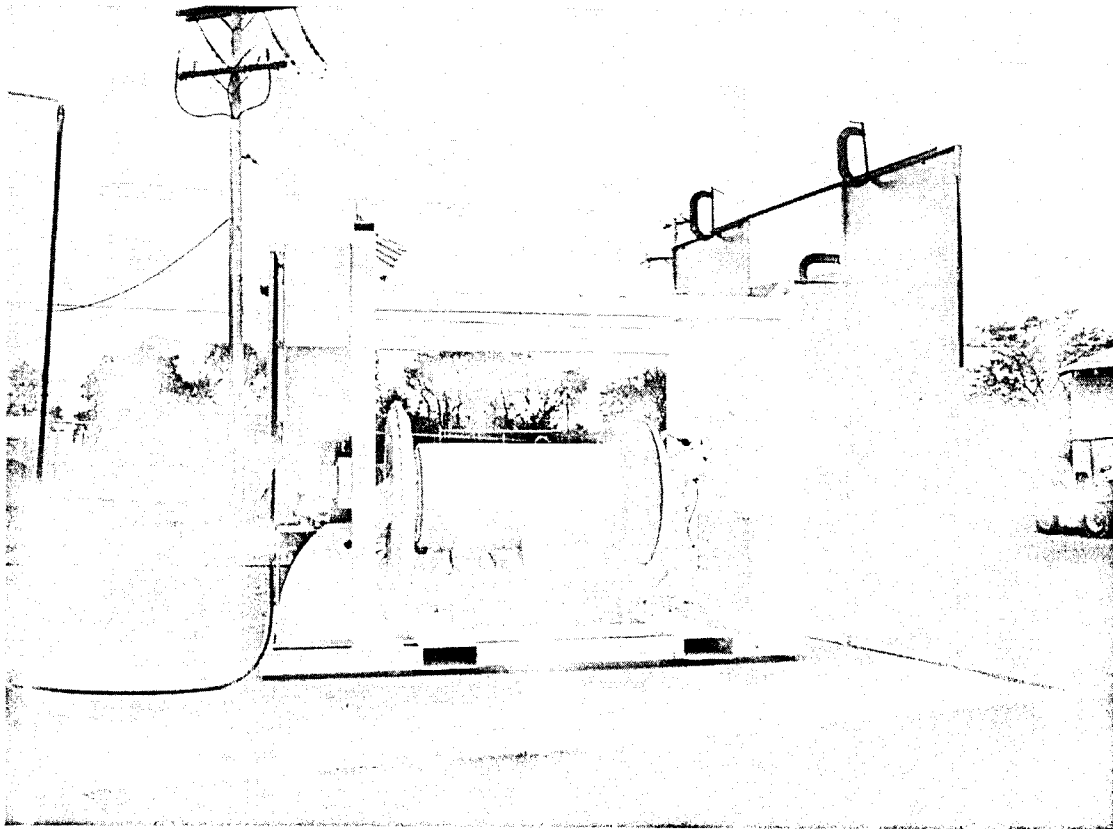


Figure 2.1-3 – Burner Assembly and Skid

The burner operates on propane gas with a maximum fuel usage of 1000 cu. ft./hr. The burner capacity is 2,500,000 BTU per hour, with a turn-down capability of 8:1 minimum. Temporary propane storage tanks are located approximately 100 feet from the pile (and burner) and are armor shielded. Propane from the tanks is supplied to the burner in a temporary configuration, using aboveground flexible hose.

FINAL

The propane fuel system includes two 500-gallon tanks to satisfy the delivery rate of 1000 cu. ft. per hour for up to 24 hours of operation. The propane tanks are provided with a fuel gauge, regulators, manifold piping, and piping between tanks and burners.

ELECTRIC POWER

Electric power is required for the combustion air fan and burner control system on the burner skid, and for the remote operator workstation. The demonstration test system is provided with a leased temporary electric power source, to simulate field conditions at a remote location. For power to the burner assembly, a diesel-powered 20 Kw, 240 volt, 3-phase electric generator with fuel tank is located in the vicinity of the propane storage tank (approximately 100 feet from the pile and burner skid). The electric generator provides electric power to the burner skid using temporary aboveground power cable. The generator is trailer mounted, and includes an integral diesel fuel tank. A larger stand-alone fuel tank is also used to fuel the generator. The electric generator is armor-shielded from the pile. A ground rod is driven into the ground in the vicinity of the generator and connected to the generator. Power to the remote operator workstation (OW) is provided by line power.

CONTROL AND DATA RECORDING SYSTEM

A local burner control panel (located on the burner skid) and a remote OW are provided for the demonstration test. The OW is housed in a control trailer located outside the perimeter of the radius of safety. The control trailer is provided with electric power (120 VAC), and heating and cooling to accommodate the OW and operators. The HGD system is operated by remote control from the OW after the burner is turned on.

The minimum distance from burner skid to the remote OW is 1250 feet, the radius of safety established by the ATC Safety Office. This safety distance was established based on the type of munitions items expected at ATC. The OW communicates with the programmable logic controller (PLC) on the burner skid using wireless modems.

The Burner Control System (BCS) includes primary measuring, indicating, transmitting, receiving, recording, totalizing, controlling, and alarming devices and appurtenances. The BCS is provided by the burner manufacturer as part of an integrated burner system. The major components of the BCS include:

- A hardwired burner flame safety system located on the burner skid. The flame safety controls and interlocks meet the requirements of the National Fire Protection Agency (NFPA).
- A PLC located on the burner skid. The PLC provides burner firing rate controls and logic for the decontamination system as described below.
- A personal computer-based OW running an off-the-shelf process monitoring and control software package. The OW is located remotely from the burner and pile (outside the radius of safety) and used to monitor parameters, adjust set points, and collect data.

The OW communicates with the PLC using wireless spread spectrum radio modems. The OW is a standard personal computer operating with Microsoft Windows NT. The computer and software have the ability to generate reports, collect historical data, and provide trending information in the form of line graphs and bar graphs, for real-time and historical data.

FINAL

The OW processes equipment graphics, continuous control and indication graphics, historical data trend graphics, and alarm logs in tabular format. The OW conveys the operational status of the process equipment, and trends (on-line and historically) of monitored and calculated signals.

The PLC and input/output (I/O) components are assembled into the burner control panel. PLC hardware, including processors, power supplies, interconnecting cables, grounding system, modules, and accessories, are in the burner control panel as shown in Fig. 2.1-2.

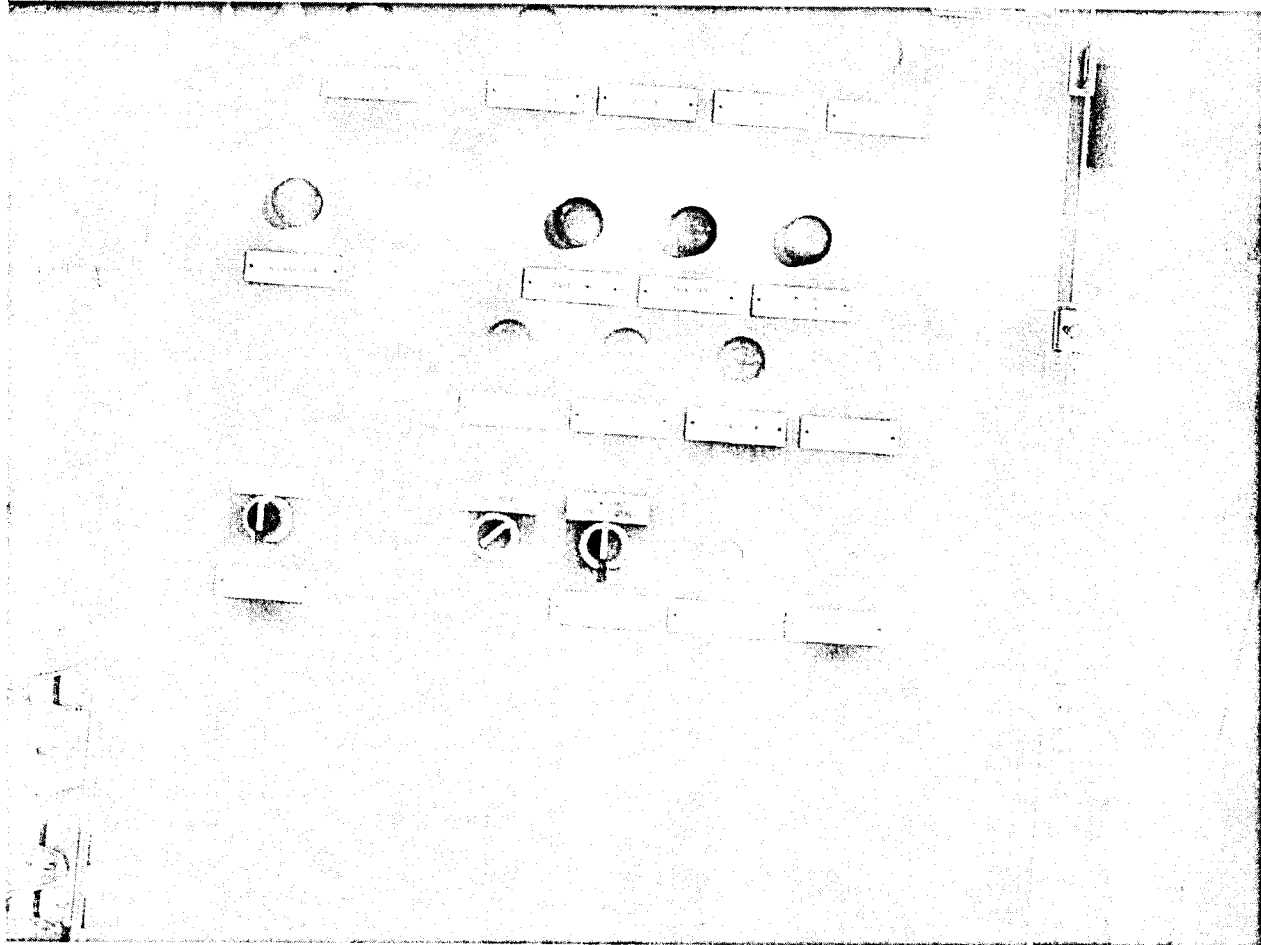


Figure 2.1-2 Burner Control Panel

CONTROL SYSTEM LOGIC/SEQUENCE OF OPERATIONS

The following logic and functions control the operation of the HGD system:

- Twelve thermocouples are strategically placed within the scrap pile and used to measure the temperature throughout the pile. The thermocouple temperature signals are input to the PLC and are used for the control functions described below.

FINAL

- The individual thermocouple temperature signals are displayed and recorded at the OW. A software selector switch is provided at the OW to allow the operator to choose which thermocouple temperature signals is used by the control logic.
- The lowest and highest thermocouple temperature signal are displayed and recorded at the OW. The high and low temperature signals are used for burner firing rate control. Two software-based temperature controllers have a temperature entered by an operator at the OW. A control signal is used as an override to control burner firing rate when the pile temperature approaches the maximum operating temperature of any component of the HGD system (insulation, thermal blanket, thermo couples, or thermocouple wire) exposed to the heat. This set point is adjustable and set to the lowest of the components' maximum operating temperature.
- The lowest temperature signal is normally used to control burner firing rate and attempts to maintain the scrap pile at the decontamination temperature set point (adjustable).
- The highest temperature signal is used as a process variable and to modulate the burner firing rate. A high temperature alarm sounds at the OW when the high thermocouple temperature signal exceeds the high temperature set point for a preset amount of time.
- A "Local-Remote" selector switch is provided at the burner panel. When the switch is in "Local" position, the burner is controlled by pushbuttons and selector switches located at the burner panel.
- When the burner is started (from the burner panel or from the PLC), it goes through a preprogrammed purge cycle. The purge cycle uses the combustion air blower to purge the burner before ignition. The exact burner start-up sequence and interlocks is as required and recommended by NFPA and the burner manufacturer.
- Normally the burner is started by the operator from the OW and stopped automatically when the decontamination process is complete. The burner operating status is indicated at the OW. When the minimum decontamination temperature is reached (i.e., all thermocouples are at or above the pre-set decontamination temperature), then the decontamination duration timer starts. The set point of the duration timer is adjustable from the OW. The time remaining in the decontamination period is also displayed at the OW.

The burner continues operating until one of the following occur:

- The preset duration of time for decontamination expires, indicating the end of the decontamination period.
- An operator at the OW presses the "Stop" pushbutton.
- Radio modem communication is interrupted.
- The fuel runs out.

If communications fail, the burner is stopped and an alarm sounds at the OW.

Burner safety alarms sound at the OW if this occurs. In addition, historical temperature and time data from the thermocouples are indicated and recorded at the OW.

2.2 STRENGTHS, ADVANTAGES AND WEAKNESSES

2.2.1 Strengths and Advantages

There is incentive to recycle and reuse high-value recyclable range scrap metal under the DoD's Resource Recovery and Recycling (R3) initiative, and financial incentives for activities to generate funds for themselves under the Morale, Welfare and Recreation Program. Many commercial recyclers have suspended acceptance of range residue, and the Defense Reutilization Marketing System is selectively refusing to accept some range residue articles. For these reasons, military activities increasingly find that they must address accumulations of range residues as a potential liability and invest assets in processing the materials.

Before commercial release for recycling, DoD policy requires certification that the scrap metal is inert. The DoD requires that range managers ensure that range residue does not contain ammunition, explosives, or other dangerous articles before release to the private sector for recycling. To accomplish this, each piece of range residue is visually inspected several times and certified as 100% free of explosives by range personnel before release for commercial recycling. Certification by visual inspection is subjective and error-prone, due to the inability to inspect inside cracks, crevices, and internal parts. The uncertainties associated with certification by visual inspection present unacceptable risk to human health for field personnel removing scrap and commercial recyclers. The high costs for inspection and certification of firing range scrap offset its recycle value. For these reasons, military activities increasingly find that they must address accumulations of range residues as a potential liability and invest assets in processing the materials.

The standard historical methods for decontamination include open burning or incineration, or surface cleaning by solvent wiping, pressure washing, or steam cleaning. Each of these methods has drawbacks related to incomplete decontamination by surface cleaning, health and safety concerns, environmental prohibitions, and/or cost. Open burning, open detonation, and flashing have become out-of-favor due to environmental concerns (spread of uncontrolled or incomplete products of combustion into the air, soil, surface water, or groundwater), and health and safety risk to range personnel. The major advantage of the HGD process over surface decontamination methods (caustic or solvent washing, pressure washing or steam cleaning) is that it works in pores, cracks, crevices, and internal parts, as well as for surface contamination. Up to 99.9% decontamination has been achieved by surface decontamination methods. Hot Gas decontamination, however, has achieved up to 99.9999% decontamination at previous demonstrations.

HGD is a transportable, low maintenance, low-operating-cost system. Because of its temporary, on-site configuration, this is an inherently low-cost method to decontaminate range residue. On-site HGD technology is a lower cost alternative to historical treatment methods, and results in less handling and transfer of explosive material and reduced hazard risk to field personnel. Hot Gas Decontamination technology fills a need for a technology to safely, effectively, and cost efficiently decontaminate firing range scrap metal.

2.2.2 Limitations or Weaknesses of HGD

Decontamination of these facilities and equipment must be undertaken in a safe, responsible, and environmentally acceptable manner. As such, there are certain conditions where the Hot Gas Decontamination system may not be applicable, or where additional safety or environmental controls must be implemented prior to application of the HGD process. This is the case when the

FINAL

application of heat at temperatures of 600°F or less may cause undue safety or environmental risk.

Some specific scenarios where limitations to the HGD technology exist (and the mitigating pretreatment measures to accommodate use of Hot Gas Decontamination). For example, if a substantial amount of explosive material is confined in a shell or other confined location, the explosive has a potential to detonate when heated under confinement. No live rounds should be placed in the range pile to be decontaminated. A first screen of range residue must be undertaken to ensure that no live rounds are placed in the pile. The HGD system is not designed to withstand a detonation of a live round without damage to the system. As would be expected, live rounds will detonate when subjected to heat generated by HGD. Scrap containing visible levels of explosives present an explosive hazard and require segregation and removal before application of the HGD process. Similarly, HGD of high concentrations of explosives in contaminated soil *in-situ* is not appropriate because of explosion potential caused by confinement of explosives in the soil.

Other items that are inappropriate for HGD include:

- Concrete-filled rounds should not be placed in the range pile. A dummy round filled with concrete, when heated above 212°F, will be subject to a steam explosion (from the water of hydration release from the concrete), unless it is opened up to relieve the steam pressure. Consequently, concrete-filled rounds must be (very carefully) opened without using heat-generating cutting or torching methods, prior to HGD. Water jet cutting and open detonation with small explosive charges are two methods for opening concrete-filled rounds.
- Friable asbestos should not be treated with the HGD process, due to potential for dispersion of asbestos. Previous HGD projects have been conducted with transite siding in building materials, with no adverse environmental effects. Friable asbestos must be removed according to regulatory requirements prior to application of HGD technology.
- Hot Gas Decontamination is not appropriate for equipment or materials with paint containing PCBs or lead. The PCB or lead in paint will volatilize when exposed to elevated temperatures. In this instance, PCB- or lead-containing paint should be removed in accordance with applicable state and federal regulations. Similarly, PCB oil or PCB residue in vessels should not be treated by Hot Gas Decontamination.
- Galvanized sheet metal, when heated above 700°F, releases toxic vapor emissions. To use HGD in this case, the galvanized sheet metal must be insulated from the hot burner gas or the temperature of the hot burner gas restricted to well below 700°F.
- Electrical wiring, electrical motors, and wood are not appropriate materials for HGD due to combustibility of the materials. These must be removed prior to initiating HGD.
- Automotive fluids, batteries, tires, and fuel tanks should not be treated by HGD and should be removed from target vehicles.
- In some instances where gross contamination exists, facilities and equipment may require surface cleaning to remove gross contamination, and to create a safe worker atmosphere for installation of the HGD system.

FINAL

- At active or closed firing or target ranges, the ground beneath a HGD system must be surveyed and cleared to a depth of two feet to be free from unexploded ordnance.

Installation of the insulation or the thermal blanket should not be undertaken during heavy precipitation (rain or snow), since the insulation will be wet and heavy, and possibly can be damaged when manipulated in this condition. Although the insulation will shed water and dry out, it is not advisable to risk damage to the material.

2.3 FACTORS INFLUENCING COST AND PERFORMANCE

As a transportable system, one of the biggest methods to reduce the unit costs is by treating large quantities of range scrap at a single installation. The economy of scale brings down the unit cost per ton to decontaminate explosives-contaminated scrap, since only one capital cost outlay for burner assembly and controls is required. Since insulation and thermal blankets can be reused, these costs are also diluted by multiple use. Also, operating experience gained at multiple piles by a single work crew will allow work to proceed more efficiently on later piles.

The time and temperature required to decontaminate a contaminated article are dependent on the type of explosive contaminant. Each different explosive material has an optimum time-temperature decontamination threshold. The time and temperature criteria each have an impact on the cost to operate. Both the heat-up time (time required to reach the pre-set decontamination temperature) and soak time (time required to hold the contaminated material at the pre-set decontamination temperature) cause the decontamination process to take a longer time (and be more expensive in terms of operations costs). Also, higher decontamination temperatures take longer to reach, and therefore are more expensive to achieve. The conclusion is that a decontamination process scenario can be focused on the particular contaminant expected (through historical knowledge, records, or analytical testing), to optimize the time-temperature requirements and minimize the cost.

A significant cost to the HGD process is the cost of the thermal blanket and insulation. The thermal blanket and insulation should be reused as many times as practicable to reduce the cost per ton. Care should be taken not to tear or damage the insulation when installing, removing, and re-using it.

Performance of the HGD system and cost will both be affected by local weather and time of year. Precipitation (rain and snow) will have a detrimental effect on pile construction, and moisture slows down operating time while it evaporates off the pile.

There are numerous active firing ranges at Army, Navy, Air Force, and Marine installations and hundreds of FUDS and BRAC sites, where HGD of range scrap can be implemented. The current trend at DoD installations is to recycle as much scrap metal as reasonably possible. Large piles of uncertified range residue scrap metal currently staged on active ranges (for example Nellis Air Force Base, Naval Air Station Fallon, Yuma Proving Ground, and White Sands Missile Range) are uneconomical and hazardous to inspect visually item by item.

For example, a recently processed Air Force scrap pile weighed 3500 tons. At a typical market price of \$80.00 to \$140.00 per ton for steel depending on its quality, that amounts to \$290,000 to \$490,000 as the maximum possible reimbursement for recycling this range residue. Crushing or cutting may be required before the material can be vended by the recycler to smelters, depending upon current demand for steel. This means that the margin for range scrap metal cleanup, which is otherwise poorly funded by DoD, is very narrow.

FINAL

HGD can allow certification of an entire pile of scrap metal in a few days, within the margin of recyclable reimbursement. HGD is a self-contained, easily transportable, low maintenance, low operating cost, Commercial Off-The-Shelf (COTS) system whose development costs have been leveraged by previous DoD funding. Previous systems emphasized total containment of fugitive emissions and thus were overly sophisticated for a range certification operation.

Previous demonstrations of HGD technology used an off-gas treatment system to treat volatilized emissions. Generally speaking, it is the off-gas treatment system which is very expensive and drives the overall system cost upwards. The off-gas treatment system typically can be 25 to 40 percent of the overall system cost. As previously discussed above and validated by this demonstration (further discussed in Section 5), off-gas treatment is not necessary for the HGD technology in the configuration addressed here.

The HGD technology can be established as a low cost, technically effective safety operation necessary for removing and recycling of high value scrap metal. *In-situ* decontamination of explosives-contaminated scrap results in less handling and transfer of explosive material and reduced hazard risk to field personnel.

3.0 SITE/FACILITY DESCRIPTION

3.1 BACKGROUND

During the planning and prior to the start of the actual demonstration, a test site was selected, cleared of any unexploded ordnance (UXO) and instrumented for test data collection. A site evaluation of available sites at Aberdeen Test Center, Aberdeen Proving Grounds MD was conducted using site selection criteria as described below. Because of the location of the largest amount of range residue, scrap metal was located in large boxes and secured in a fenced-in area of Ammunition Dump 3 (AD-3). A nearby test range, Air Base Range 9 (ABR-9), was selected to conduct the HGD demonstration. The results of the evaluation concluded that Air Base Range 9 (ABR-9) at ATC was best suited to conduct the HGD demonstration. Selection criteria for the test site were established as described as follows:

Safety – The site needed to be large enough to accommodate the ATC-required 1250-foot safety zone between the scrap piles and any non-test-related personnel. ABR-9 meets this requirement.

Location – The largest amount of range residue scrap metal was located in large boxes and secured in a fenced-in area of Ammunition Dump 3 (AD-3). The site needed to be in close proximity to the largest pile of scrap and needed to be remote enough that it would not interfere with any other test operation. ABR-9 is the closest test site to AD-3.

Infrastructure – The site needed power for the test instrumentation but this was not a requirement for the technology application. A diesel-fueled generator powered the project. Also, ATC provided line power to the demonstration site at ABR-9.

Security – To maintain the inspection certification, to reduce the chance of commingling unacceptable items into the pile, and to limit access to the site during operations, a fenced-in area was needed. Air Base Range 9 is surrounded by trees on three sides and partially fenced in on the fourth side. ATC temporarily completed the fence on the fourth side for the duration of the demonstration.

Site History – The site selected had to be part of a firing range that would possibly have had range scrap piles awaiting explosive decontamination and thus representative of a typical HGD site.

Before the start of the HGD demonstration, ATC explosive test operators performed an unexploded ordnance (UXO) magnetometer sweep of ABR-9 in accordance with Standing Operating Procedures (SOPs) 385-2384, "Conducting Magnetometer Sweeps"¹⁵ with no UXO found.

3.2 SITE/FACILITY CHARACTERISTICS

ATC Air Base Range 9, shown in Figure 3.1-1, was used to test anti-tank land mines, which contained up to 15 pounds of TNT and Comp B. Testing usually involved detonating one mine at a time below a tank. Prior to conducting the HGD demonstration, the area is used frequently for demilitarization operations on live ordnance.

Figure 3.1-2 shows that the soil classification at Range 9 is Romney Silt Loam (RoA) with soil pH 3.5 to 6.5. In addition, the depth to water is about 20 to 25 ft from the surface and flows in a

FINAL

southeast direction.

Before the start of the HGD demonstration, ATC explosive test operators performed an unexploded ordnance (UXO) magnetometer sweep of ABR-9 in accordance with Standing Operating Procedures (SOPs) 385-2384, "Conducting Magnetometer Sweeps"¹⁵ and 385-2048, "Destruction of Dud Ammunition Located on Ground Surface"¹⁶.

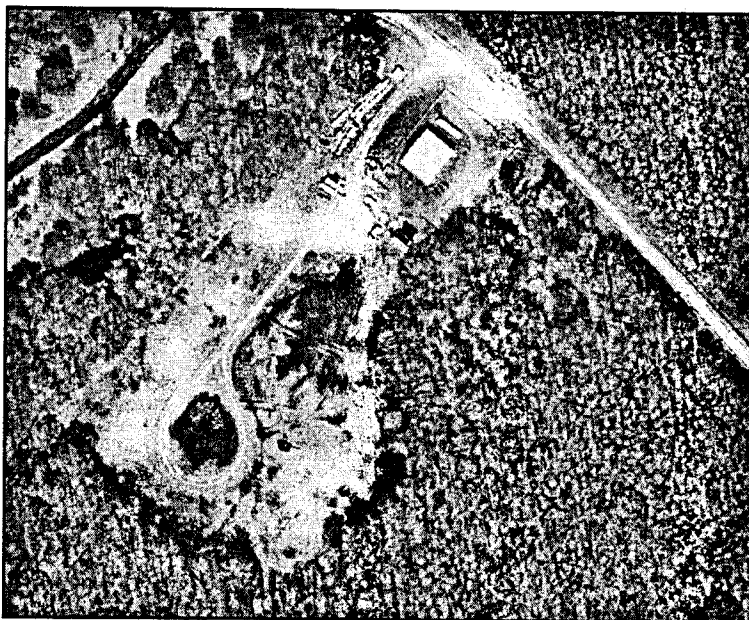


Figure 3.1-1 Air Base Range 9

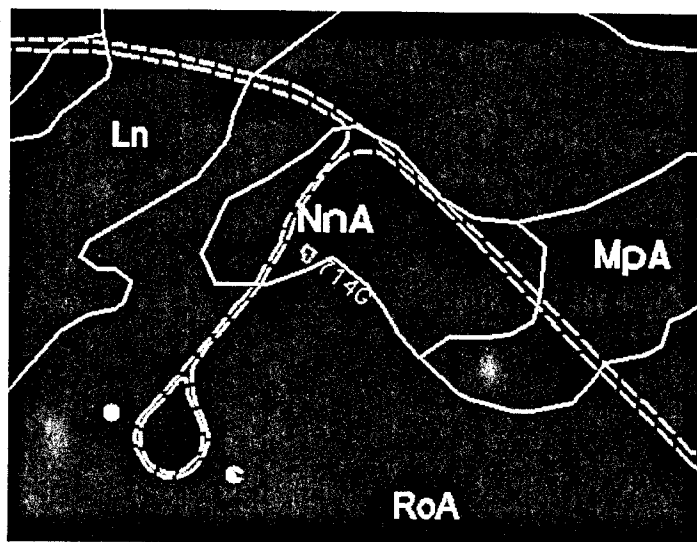


Figure 3.1-2 Air Base Range 9 RoA Soil Type

4.0 DEMONSTRATION DESIGN

4.1 PERFORMANCE OBJECTIVES

The performance objectives of the demonstration test are simple and straightforward. The demonstration's primary objective is to provide effective HGD of range scrap in a pile configuration using the transportable HGD system described above. Secondly, the demonstration sets out to provide HGD at a lowest possible cost, by optimizing operating parameters such as decontamination temperature and time and physical parameters such as scrap pile size and insulation thickness. A summary of the performance objectives for the demonstration test from the Final Demonstration Plan¹⁷ (Appendix B) is presented in Table 4.1-1. Methods and parameters to meet these goals are described in the following sections.

**Table 4.1-1
Performance Objectives**

Type of Performance Objective	Primary Performance Criteria	Expected Performance (Metric)
Quantitative	1. Prove HGD decontamination effective to remove or destroy explosive contaminants	No detectable amount of explosives on spiked coupons
	2. Prove HGD equipment meets performance criteria	Thermocouples and control system measure and record time and temperature
	3. Meeting regulatory standards for fugitive emissions	MDE determined based on data collected
	4. Low cost per ton	<\$300/ton
Qualitative	1. Reduce HGD operating costs	Shorter time for decontamination
	2. Safe operation of the system	No serious injuries
	3. Ease of use	Operator acceptance

To minimize labor costs, one test objective was to complete operation of the decontamination test for individual piles in one day, and preferably in one shift. The demonstration tests further explore and confirm previous test data with regard to time and temperature for decontamination runs. The intent is to optimize the time and temperature requirements for effective decontamination in order to decrease the overall time it takes to operate the HGD system.

4.2 PHYSICAL SET-UP AND OPERATION

4.2.1 Test Setup

Parsons engineered the system that was developed by U.S. Army Environmental Center (USAEC) by combining a 2.5 million Btu propane burner with several high temperature

FINAL

insulating blankets. The skid-mounted propane burner, the control system and the operator workstation were manufactured and/or assembled by Hauck Manufacturing Company.

The hot gas decontamination (HGD) system consisted of the following major components:

- Skid mounted 2.5 million Btu propane burner and control system.
- A remote personal computer based operator workstation.
- A 20-kilowatt diesel generator with an auxiliary fuel tank.
- Two 1000-gallon propane fuel tanks and plumbing.
- Sixteen thermocouples.
- Thermal blankets, wire mesh and chicken wire.
- Spiked coupons with known quantities of explosives.

Detailed engineering specifications and drawings, and operating instructions for the transportable HGD system are presented in the Implementation Guidance Manual¹⁸ for the project. Also, an instruction video has been prepared by the Aberdeen Test Center for project implementation. The above listed HGD system components are shown in figures 4.2-1 through 4.2-7. For test purposes the range was equipped with 2 stadium style lights, two remote controlled video cameras, 3 large shields, 24 ambient air emissions monitors and 4 continuous emissions monitors with a data trailer run off of APG house power. These test required items are shown in figures 4.2-8 through 4.2-13.

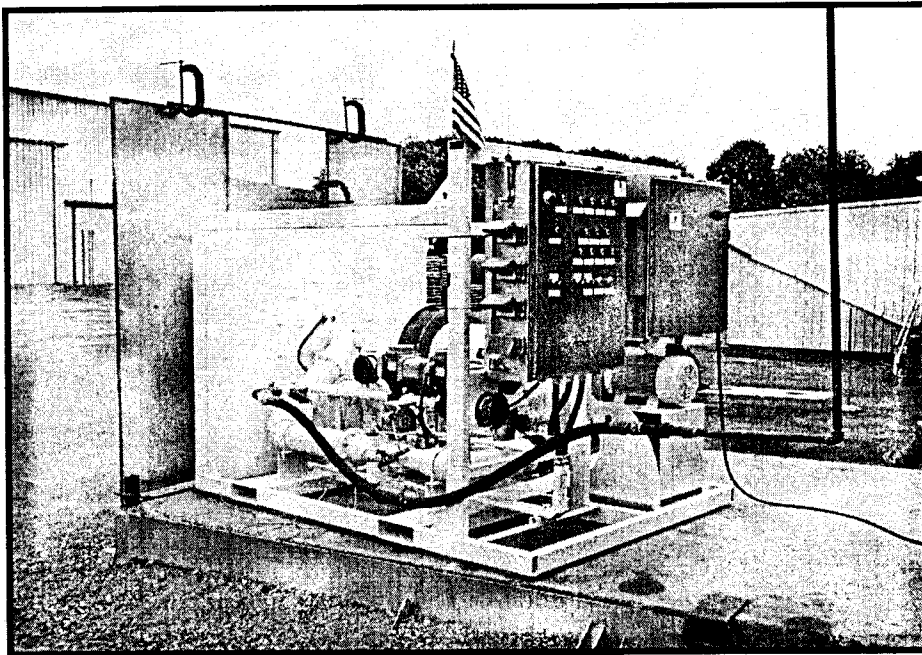


Figure 4.2-1 - Skid Mounted 2.5 Million Btu Propane Burner And Control System.

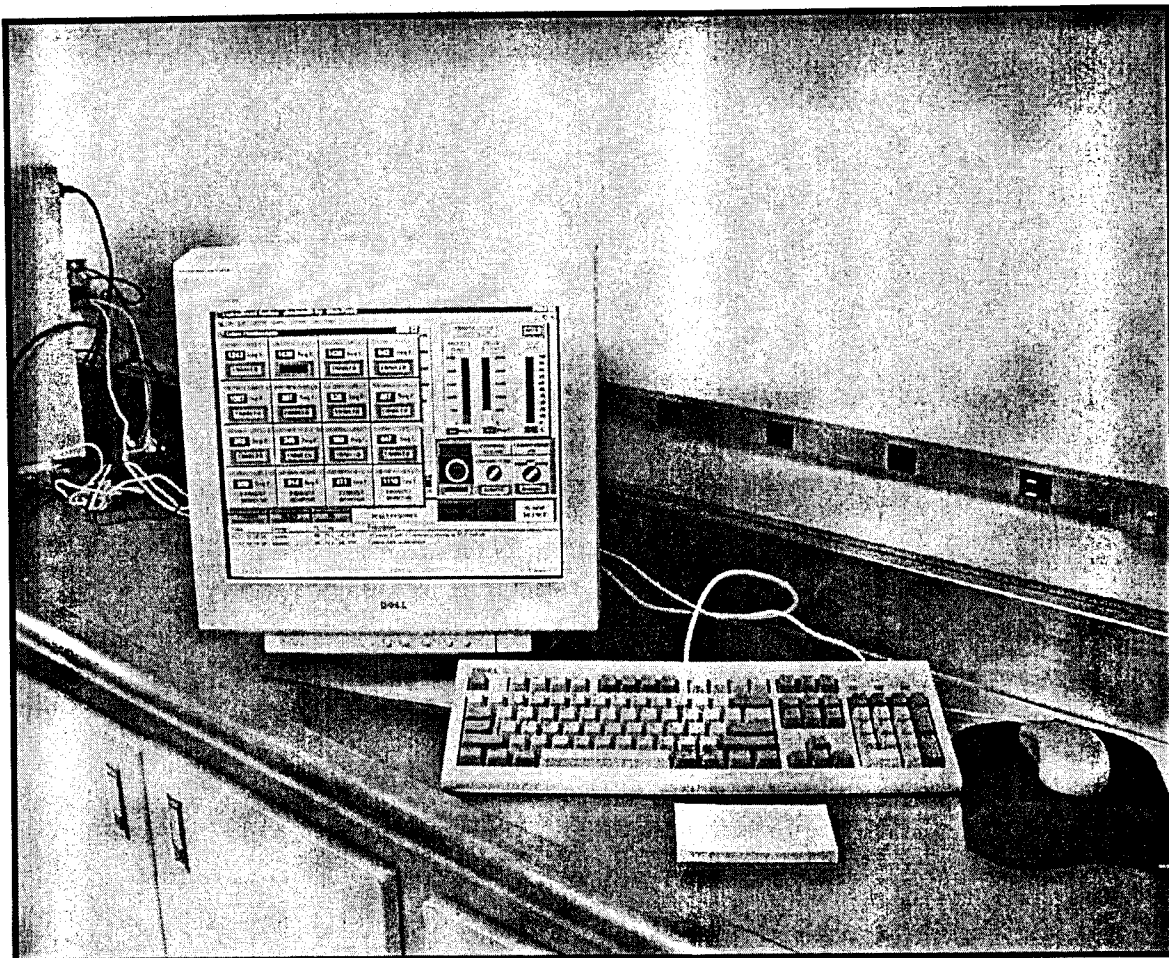


Figure 4.2-2 - A Remote Personal Computer Based Operator Workstation.

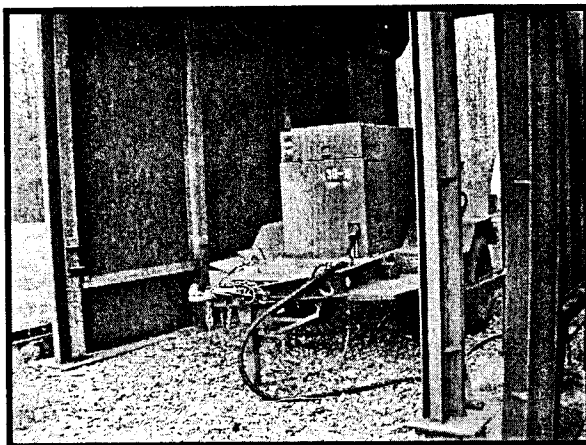


Figure 4.2-3 - A 30-Kilowatt Diesel Powered Generator and 500 Gallon Auxiliary Tank.

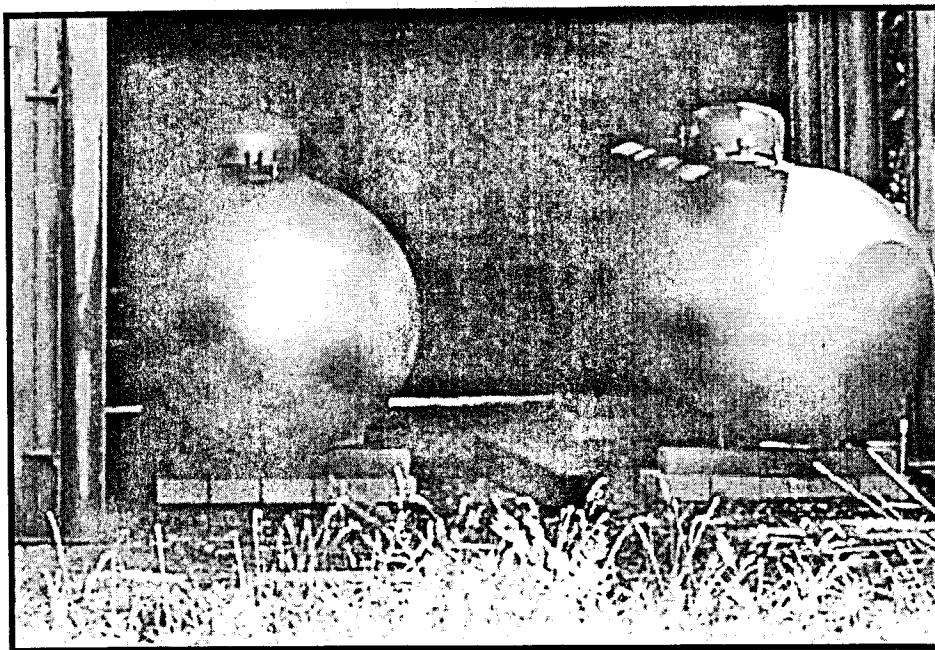


Figure 4.2-4 - Two 1000-Gallon Propane Fuel Tanks.

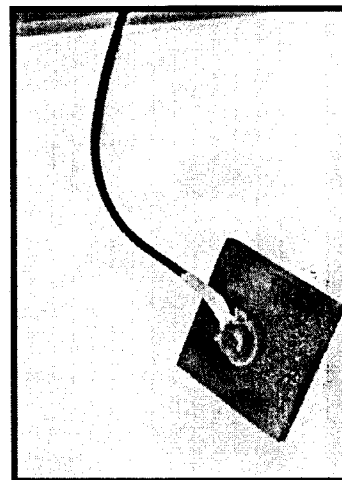
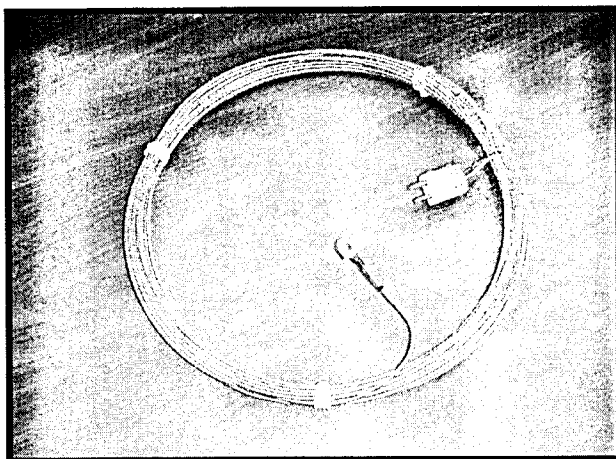


Figure 4.2-5 - K - Type Thermocouple and Plate

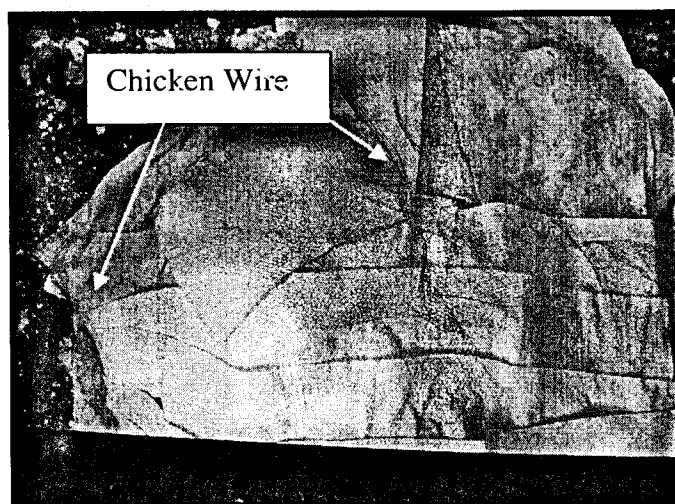
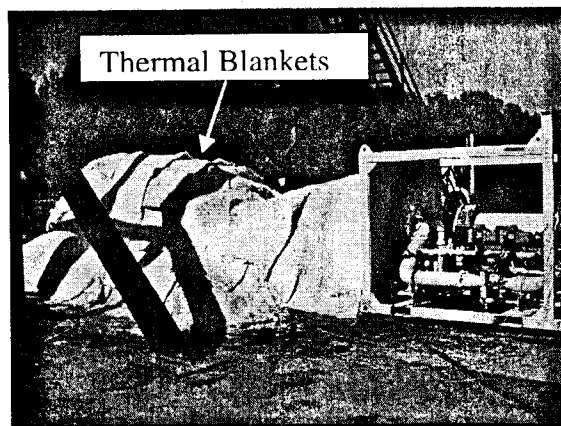
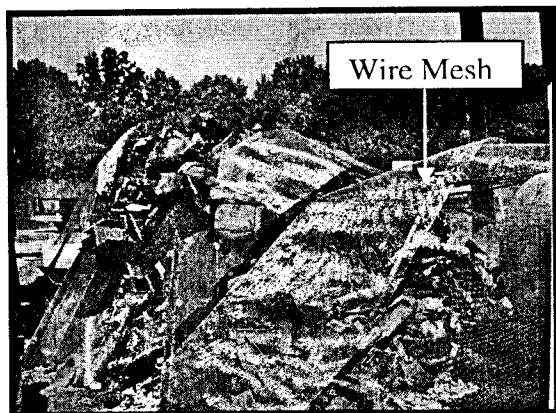


Figure 4.2-6 - Wire Mesh, Thermal Blankets and Chicken Wire.

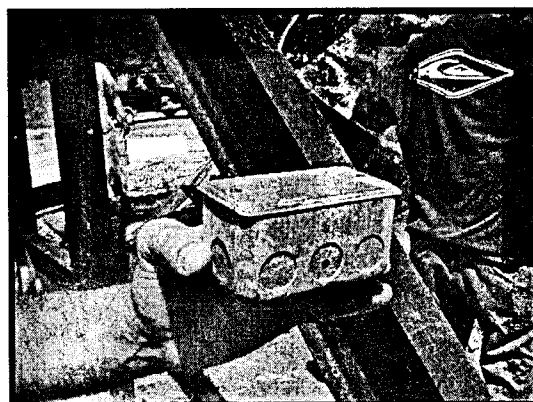
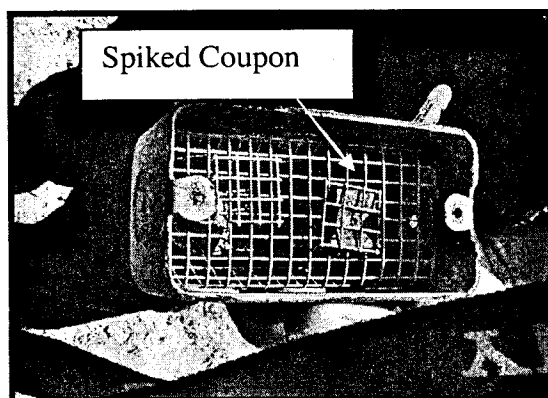


Figure 4.2-7 – Inside and Outside Views of Spiked Coupon Box

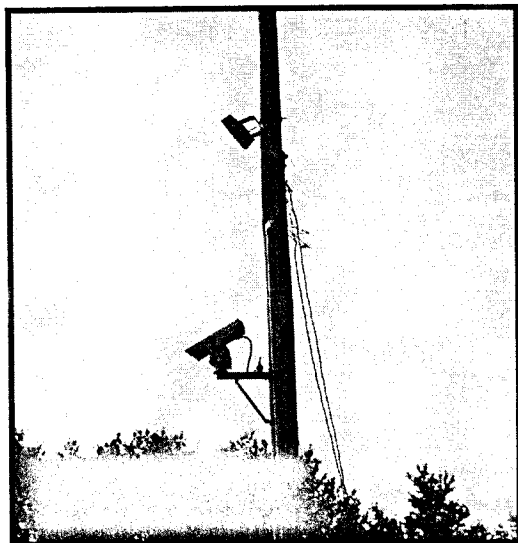


Figure 4.2-8 – Range Light and Camera



Figure 4.2-9 – Range Shield for Data Trailer

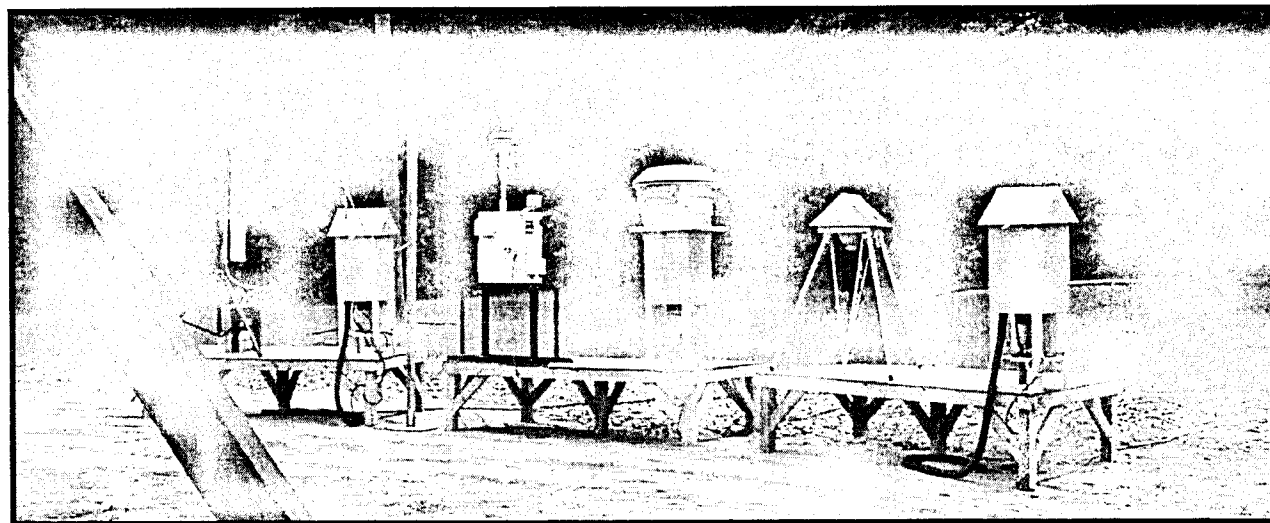


Figure 4.2-10 – One of Four Sets of Ambient Air Emissions Monitors (From Left to Right - Volatile Organic Compounds (VOC's), Explosives, Particulate Matter less than 2.5 Microns (PM 2.5), Particulate Matter less than 10 Microns (PM 10), Total Suspended Particulate Matter (TSP), Polycyclic Aromatic Hydrocarbons / Semi-Volatile Organic Compounds (PAH/SVOC's)).

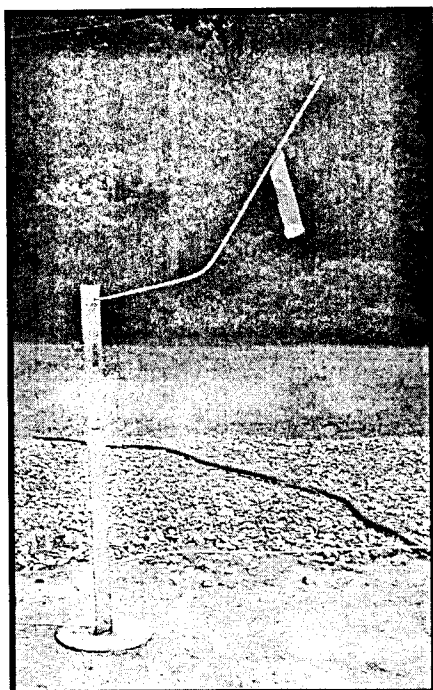


Figure 4.2-11 – Continuous Emissions Monitoring (CEM) Collection Tubing (One of Four Locations)

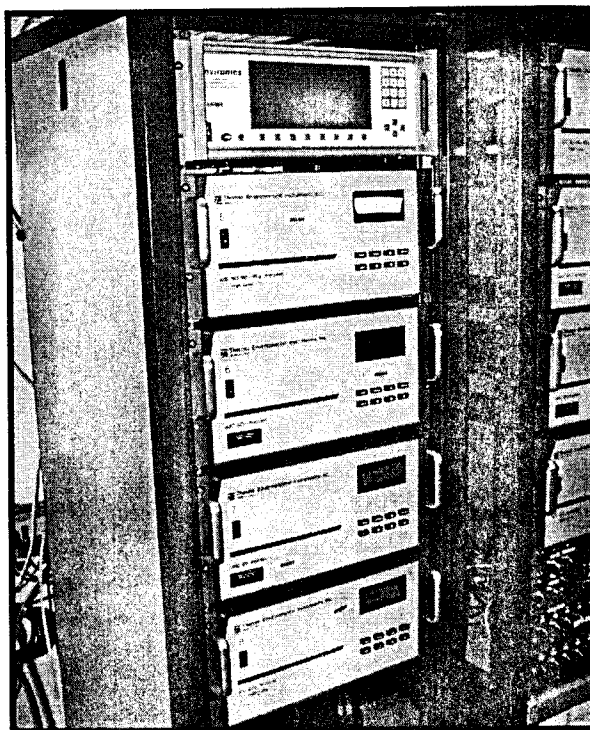


Figure 4.2-12 - Rack (top to bottom) containing (Top) EnviroNics Computerized Gas Mixing/Dilution Instrument, Thermo Environmental Instruments model 42C, high level NO_x analyzer, TEI model 43C for SO₂ analyzer, TEI model 48C, high level CO analyzer, TEI model 41C, high level CO₂ analyzer.

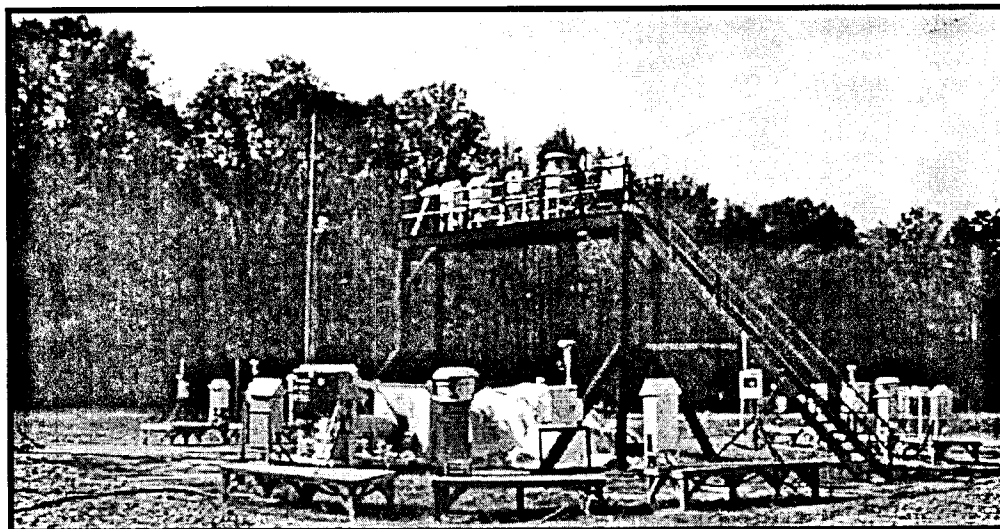


Figure 4.2-13 – Range Completely Set-up for Testing

FINAL

The ground underneath each test pile and in the immediate vicinity of the test pile was level and free of vegetation and debris. A 6-inch layer of crushed gravel was placed leading up to and underneath the pile because wet weather and mud at the site was impeding work. Vegetation and undergrowth was cut and removed within 100 feet of the test pile. An aerial view of the test site is presented in Figure 4.2-14.

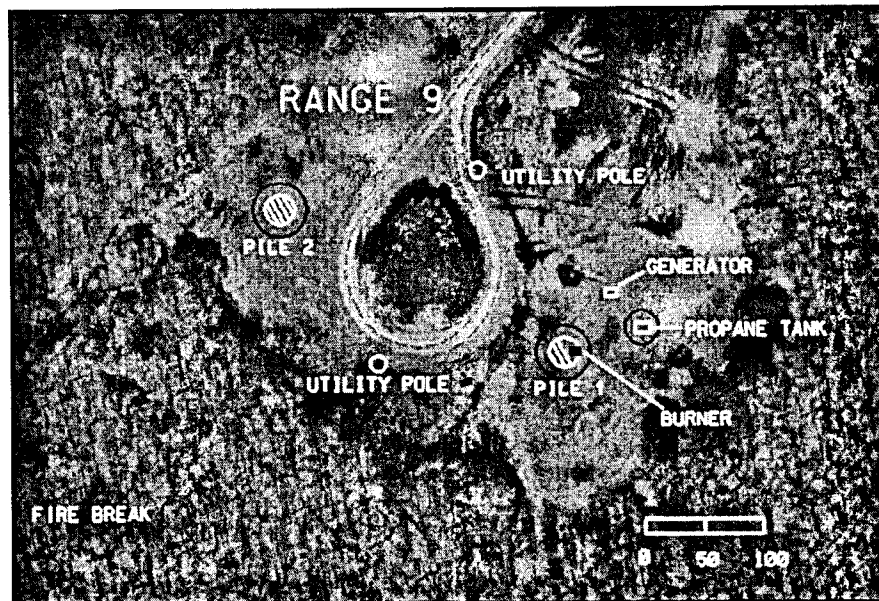


Figure 4.2-14 Test Setup at ABR-9

Formation of the Test Pile: The range scrap used in the seven test trials were collected from many areas of the ATC firing range, inspected and secured in lockable dumpsters or wooden boxes. Figure 4.2-15 shows a typical dumpster and a wooden box used to secure the inspected range scrap. Approximately 14.5 tons of range residue were used to form Pile 1 that was used for the first through the fifth test trials. Pile 1 was approximately 20.5 feet wide by 18 feet long by 7 feet high. The scrap consisted of reactive armor tile boxes and covers, cut open large caliber projectiles and bombs, as well as range targets. Range targets varied from I-beams, vehicle parts to various thickness and sizes of armor plate.

The scrap was secured behind a locked fence until being moved to test area. Although the scrap was secured against commingling with scrap that was not inspected, it was outside on the range and exposed to the elements. During the formation of the test piles, it was noted that there was a significant amount of water in the containers. An inventory of the contents of Pile 1 is shown in Table 4.2-1.

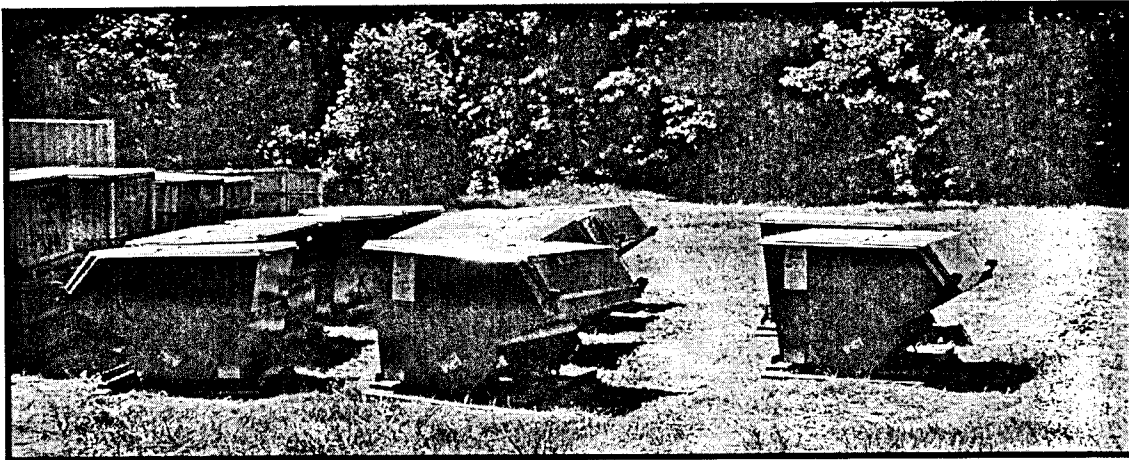


Figure 4.2-15 - Dumpsters and Wooden Boxes Used To Store Inspected Range Scrap

Table 4.2-1.
Pile 1 Contents

Type Of Round	Number of Items	Detonation Charge Used To Split Open Projectile
8"	55	0.75 to 1.25 lbs of C-4
175-mm	56	0.75 to 5.0 lbs of C-4
155-mm	13	1.25 to 3.0 lbs of C-4
105-mm	1	1.25 lbs of C-4
100-mm	1	1.25 lbs of C-4
60-mm	1	1.25 lbs of C-4
4.2" Mortar	1	0.75 lb. of C-4
2.75" Rocket Head	1	0.75 lb. of C-4
120-mm Mortar	1	1.25 lbs of C-4
150 lb. Bomb	1	1.25 lbs of C-4
90-mm HEAT	1	0.50 lb of C-4/1.80 lbs Ex.
40-mm Grenade	2	0.50 lb of C-4/0.78 lb Ex.
Armor Tile Covers	12.5 yd ³	None, visually inspected only

Pile 2 was used for the sixth and seventh test trials and contained much smaller pieces of range scrap, mostly munitions fragments weighing approximately 20 tons. Pile 2 was 13 ft. 7 inches wide by 23 feet 7 inches long by 6 feet high.

INSULATION AND THERMAL FABRIC

The range residue pile is insulated with standard high-temperature industrial insulation and high-temperature thermal fabric. The order of placement of materials is as follows:

Bottom layer – Heavy wire mesh (hog wire) is used to support the insulation and prevent damage from sharp objects in the pile during installation. Stainless steel wire mesh is used in the vicinity of the burner (front half of pile) to resist damage at high temperatures. Carbon steel wire mesh (not galvanized) is used in the rear of the pile away from the burner to save cost.

FINAL

Second layer – A high temperature insulation layer is placed to conform to the pile shape. Care should be taken not to damage the insulation during installation or removal. The insulation is planned for reuse on subsequent piles. Insulation should be stockpiled out of the weather when not in use. During installation, the insulation was overlapped with the previous strip to seal seams.

Top layer – Light wire mesh (chicken wire) is used to hold the insulation layer in place from displacement due to wind and weather. The wire mesh is pinned to the ground to secure the insulating system in place.

SAFETY CONSIDERATIONS

The safety of workers and the public health has the top priority in constructing the test pile and operating the demonstration test.

The range residue pile is located and constructed to minimize potential for both explosion and fire due to combustion of combustible materials exposed to the heat of the process. Fire extinguishers were provided by APG. The USAGAPG Fire Protection Branch was briefed on the nature and hazards of the demonstration test.

A geophysical survey was conducted at the site of each demonstration test pile for unexploded ordnance (UXO) lying underneath before construction of the range residue pile. No UXO were detected during this activity. There was no digging or intrusive activities associated with the demonstration test without prior geophysical survey for UXO. Also, at the site of the electric power generator, a geophysical survey for UXO was conducted for placement of the ground rod.

The range residue pile was free of trash, paper, cardboard, and wood products, and limited to range residue (shrapnel and range target scrap metal). Range residue was inspected and certified to be free from live munitions and quantities of explosive materials that create danger of detonation.

A radius of safety was established where test personnel and installation personnel are prohibited from entering during test operation (when the last thermocouple reads less than 120°F). Because of uncertainties with regard to explosive hazards during the test, a conservative radius of safety of 1250 feet was established for the test when the last thermocouple reads less than 120°F. Operators are not permitted to enter the radius of safety while the burner is operating. The HGD system is designed to operate remotely from outside the radius of safety. For fire safety, the HGD test at ATC was attended full time when operating, and for at least one hour during cool-down after the burner has been shut down. Closed-circuit television (CCTV) monitoring at a remote location on APG may be used to monitor the pile during cool-down.

Extra care was exercised by workers when handling (sharp) scrap metal when constructing the pile. Work gloves, steel toed boots, and long pants and long-sleeve shirts were required. Special care was exercised when and if reaching into the pile is necessary to place or move coupons, thermocouples, or thermocouple wires.

A direct line of sight from outside the radius of safety to the pile was maintained from at least two vantage, including one direct line of sight to the burner assembly, and to the fuel/generator site.

FINAL

Closed-circuit television (CCTV) was used for in-close visual monitoring of the pile or burner assembly during burner operations. CCTV was provided by ATC. For fire safety reasons particular to the demonstration test at APG, the demonstration was attended at all times during burner operation.

Non-participating installation personnel and visitors were kept outside the radius of safety through the use of warning signs and announcements at installation safety briefings.

SECURITY CONSIDERATIONS

The demonstration test was conducted inside the high security fence at the Aberdeen Test Center, which in turn is inside the perimeter fence at Aberdeen Proving Grounds. In addition, a third and close level of security was provided by a fence along the road at the test site at ABR-9. The gate to the road at ABR-9 was kept closed and locked at all times when the site was unattended, and when the burner was operating. Security measures for the scrap and pile were effective when the scrap was certified as free from live munitions and Ammunition, Explosives, and Dangerous Articles (AEDA), to ensure that no uncontrolled, uncertified scrap or AEDA was inadvertently placed in the pile.

Range residue was controlled and secured from the time it was certified as free from live munitions and AEDA. Range residue that had been decontaminated was loaded into lockable containers, and locked and tagged according to ATC procedures.

4.2.2 Test Operation

The period of operation for the seven demonstration tests was between 16 August 2001 to 24 October 2001. Specific test dates are as follows:

Test Number	Date
Test 1	16 Aug 01
Test 2	5 Sept 01
Test 3	18 Sept 01
Test 4	28 Sept 01
Test 5	4 Oct 01
Test 6	16 Oct 01
Test 7	24 Oct 01

Dates and durations were coordinated with ATC range operations.

The quantity of range scrap treated depends on the exact size of the scrap pile. The design basis for the pile size is a semispherical shape, 8 feet high by 18 feet in diameter. The density of the scrap metal varies with the type of metal treated (i.e., steel, aluminum, or others). The scrap metal generated at ATC is mostly steel, and the measured density of range scrap generated at ATC is 53 lbs. per cu. ft., from ATC data from previous scrap shipments. The quantity of scrap tested in the density tests was between 15 and 20 tons. For the demonstration test, one week was allowed in the schedule for each pile. The actual test performance was conducted in 7 tests covering 10 weeks or one test every 10 days on average.

Residuals Handling

Any range residue resulting from the demonstration activities is to be handled, treated, or prepared for offsite disposal in accordance with range residue and solid waste protocols. The range residue is handled in accordance with ATC SOP 385-2389, Planning the Disposition of Range Residue and Management of the Range Residue Consolidation Facility¹⁹. In summary, SOP 385-2389 states that the range residue will be inspected (if required), appropriate signatures will be acquired for rendered-safe certification, radiation clearance certification, inert certification, demilitarization (DEMIL) certification, etc., and will be sorted and secured for final sales through the Defense Reutilization and Marketing Office (DRMO) at Fort Meade.

Approximately 2000 pounds of thermal blankets were used up during the 7 trials performed during the HGD demonstration. Analysis for metals and explosives from 10 random samples taken from the used thermal blankets revealed that the blankets could be disposed of as a solid waste (trash), rather than as a hazardous waste. Disposal cost for the blanket as a solid waste (no explosives or metals) is approximately \$50.00 for the entire 2000 pounds.

Operating Parameters for the Technology

The HGD process for range scrap in the range pile configuration is a batch operation. The effectiveness of the process is both time and temperature dependent, the two primary operating parameters for decontaminating explosives-contaminated range scrap. Depending on the type of explosive contaminant, decontamination temperatures between 500 to 600°F and holding times between 1 and 6 hours have been shown to be effective.

Operations costs are the primary motivation to reduce the overall operating time for the system; with the objective of minimizing or eliminating premium overtime work (paid time and a half or double time, or work on swing shift and graveyard shift).

The overall time to operate the burner includes the heat-up time plus heat-soak time, but does not include cool-down time. Physical parameters which affect the time to operate the system include the pile size, the thickness of insulation applied over the pile, and the heat input from the burner, as follows:

- A smaller pile requires less time to heat up and soak at temperature than a larger pile.
- A thicker insulation layer (or multiple layers) holds heat better, resulting in shorter heat-up times.
- The heat input is a characteristic of the burner size, turn-down ratio, and control and operation. The burner size and turn-down ratio have been designed and specified for the demonstration test at 2.5 million BTU/hr and 8:1 turn-down respectively.

The burner was throttled back in the event that the maximum allowable temperature of the insulation product is met or exceeded near the burner outlet. In this case, the heat input is decreased and the heat-up time extended while the heat is conducted from the hot end to the cold end of the pile.

One critical issue affecting cost for processing is the time to heat the scrap pile. Shorter heat-up time equals lower labor and fuel cost. The heat-up time is highly dependent on the effectiveness of insulating the pile. The insulating characteristics of the insulation blanket to contain heat (blanket thickness/number of layers, leakage at seams/overlapping of seams, leakage at edges, and securement methods) were evaluated and progressively improved during each test run.

FINAL

In addition, some qualitative observations regarding pile size may be made during the progression of tests, and some adjustments in pile size (larger or smaller) may be made in later tests.

To monitor for safety and performance, two video surveillance cameras were mounted on the utility poles shown in Figure 4.2-14. Both cameras recorded simultaneously. Each camera had pan and tilt capability with zoom lens control, and the video signal was routed back to the instrumentation trailer. The test site operator was able to remotely observe the operation and report on any test incidents.

Test performance data was documented using the Automated Test Incident Reporting System (ATIRS) database. The ATIRS Web site provides authorized access to raw data, documents, spreadsheets, reports, images, and video clips related to test projects. The test performance data includes daily summaries, test incident reports (TIRs), diesel fuel and propane usage reports, manpower reports, thermocouple raw data, and any test-related pictures and video clips. An overview of the ATIRS system can be accessed on the Internet at <http://vision/whatis.html>.

Operational performance parameters (decontamination time, soak temperature, heat input and heat-up time) were varied over the course of the demonstration test to optimize the decontamination process. To establish performance limitations for common explosive compounds (TNT, HMX, and RDX), the time and temperature for decontamination was progressively decreased during successive tests. In addition, engineered and physical characteristics of the decontamination system (scrap pile size and configuration and insulation system) were varied during the demonstration test. The test matrix indicating the purpose of individual demonstration tests from the Final Demonstration Plan¹⁷ (Appendix B) is presented in Table 4.2-1. Note that the demonstration once underway did not strictly follow the test matrix for individual test (in fact the test matrix was accelerated) as will be discussed further in Section 5.2.

Twelve thermocouples were strategically located within the scrap pile to measure temperature and the effectiveness of the burner to heat the pile to the desired temperature. Co-located with the thermocouples were the spiked metal coupons. The thermocouples were used to monitor temperature at various locations in the pile and monitor the progress of each demonstration test. The thermocouples in combination with metal coupons spiked with explosives provide analytical data that the demonstration of the HGD process was effective. The metal coupons were spiked in the laboratory with known quantities of three types of explosives (HMX, RDX, and TNT). Each coupon is a 1-1/2 cm by 1-1/2 cm square of either 0.8 mm thick steel or 1.6 mm thick steel. Each coupon was spiked with approximately 1 mg of explosive. The coupons were analyzed for explosives residues after each test to measure the success or failure of the HGD process at the time and temperature criteria for that particular test.

FINAL

Table 4.2-1
Decontamination of Range Scrap at Aberdeen Test Center

Test No.	Description	Test Objective	Pile No.	Pile Size	Soak T (°F)	Soak Time (hours)	Test Results Needed	Notes
1	Proof of Concept	Effective decon at 600/6	1	18'D x 8'H	600	6	Number	
2	Decrease Soak Temp/Time	Shorten run time	1	18'D x 8'H	550	6	Test 1	
3	Decrease Soak Temp/Time	Shorten run time	1	18'D x 8'H	500	6	Test 1 & 2	
4	Decrease Soak Time	Shorten run time	1	18'D x 8'H	See note	4	Test 1, 2, 3	Soak T depends on tests 1, 2 and 3
5	Decrease Soak Time	Shorten run time	1	18'D x 8'H	See note	2	Test 4	Soak depends on tests 1, 2 and 3
6	Decrease Soak Time	Shorten run time	1	18'D x 8'H	See note	1	Test 5	Soak T depends on tests 1, 2 and 3
7	Burner Full Bore	Max T/shorten run time	2	18'D x 8'H	Field deter	Field deter	Test 1 to 6	Keep hot thermocouples below 1200°F
8	Alternate Burner Setting	Decrease T and run time	2	18'D x 8'H	Based on tests 1 to 4		Test 1 to 7	
9	Spare	Validate results/redo	2	18'D x 8'H	Based on tests 1 to 5		Test 1 to 8	
10	Relocate to New Pile	Optimize pile size	3	Field determined	Based on tests 1 to 6		Test 1 to 9	
11	Relocate to New Pile	Optimize insulation	4	Field determined	Based on tests 1 to 7		Test 1 to 10	
12	Spare	Validate results/redo	TBD	TBD	TBD	TBD	Test 1 to 11	

FINAL

A majority of the thermocouples (eight) were located in projected cold spots in the pile, in high and low locations on the far side from the burner near the outside of the pile. Spiked explosive coupons (provided by Cold Regions Research and Engineering Laboratory [CRREL] in metal coupon holders) were placed at each of these thermocouple locations (cold spots only), within approximately six inches of each thermocouple. These eight thermocouples and lead wires were carefully placed near the outside of the pile (within one foot of the perimeter) and protected from damage during subsequent piling of scrap metal overtop.

In the first test piles, thermocouples were placed along the center axis of the pile to monitor the progress of heat transfer during the test. These thermocouples and their respective lead wires were protected from damage during subsequent pile construction by placing the thermocouples, and lead wires under a protective large steel I-beam. A schematic plan of the distribution of thermocouples in the pile is presented in Figure 4.2-16.

At least two thermocouples were placed in the immediate vicinity of the burner exit, to monitor that the pile does not exceed maximum temperature limitation of the materials in the pile. The maximum temperature limitation of the pile is determined by the maximum temperature limitation of the thermal insulation near the burner exit.

Temperature profile data was collected at the operator workstation (OW) during the tests. Test personnel prepared a sketch of thermocouple locations within the pile. The sketch references thermocouples by tag number and shows their location. It is important that the correct thermocouple then be connected to the appropriate control system input. Using the sketch and thermocouple tag number, the temperature profile within the pile can be accurately portrayed and analyzed.

Thermocouple wires exit the pile such that they are routed to the burner control panel. Thermocouple wires were not placed under or through the pile (except protected as described above for thermocouples along the center axis).

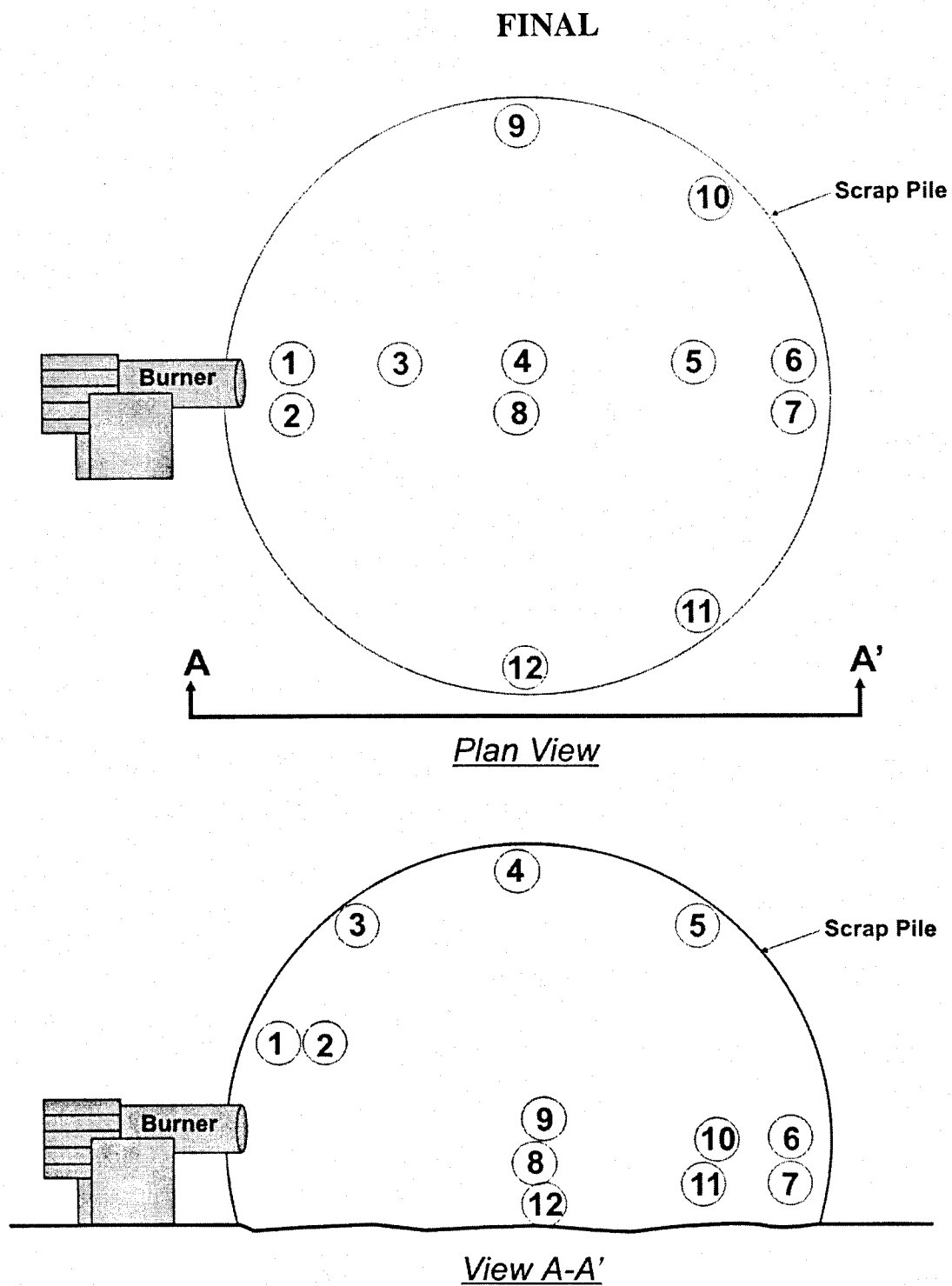


Figure 4.2-16 Typical Arrangement – Thermocouple Location in Pile

4.3 SAMPLING AND ANALYSIS PROCEDURES

4.3.1 Spiked Coupons

Spiked Coupon Preparation. Metal coupons were made by cutting 1.5 by 1.5-cm squares from a 1.6mm thick sheet of steel. Actual pictures of the inside and the outside views of a spiked coupon box are shown in Figure 4.3-1.



Figure 4.3-1 – Inside and Outside Views of Spiked Coupon Box

A dimple (slight depression) was made in the center of each coupon with a 4.8mm center punch to hold the liquid aliquots used to transfer the explosive analytes. In addition, the surfaces of the steel coupon were rapidly oxidized using dilute solutions of hydrochloric acid and nitric acid and a saturated sodium chloride solution. The metal coupons were also repeatedly heated to temperatures greater than 1000 °F. The coupons were oxidized (rusted) so that they would be in a condition similar to the range scrap. This oxidation step was performed prior to coupon spiking. A coupon of this size is large enough to hold a 5µl aliquot of spiked acetonitrile on the surface during spiking, yet small enough to fit into, and lay flat on the bottom of a standard 40 or 20ml VOA vial for residue recovery.

Stock solutions of TNT, RDX, and HMX for spiking the coupons were both purchased and prepared in-house. Both were used to spike the coupons. The purchased concentrated standards of TNT (50mg/ml in acetone), RDX (20 mg/ml in a mixture of MEK: methanol acetone) and HMX (20 mg/ml in methanol) were purchased from AccuStandard Inc (New Haven, CT).

In-house standards were prepared by adding solid material to the solvent. The solubility of TNT in acetone is about 109g per 100g at 20 °C, and this analyte has nearly as high of solubility in acetonitrile. A concentrated stock solution was prepared by dissolving 1g of TNT into 5ml of acetonitrile (0.2 g TNT/ml). The solubility of RDX in acetonitrile is about 12g per 100g at 30 °C. A concentrated stock solution for RDX was prepared by dissolving 1g of RDX into 25ml of acetonitrile (0.04 g RDX/ml). The solubility of HMX in acetonitrile is about 2g per 100ml. A concentrated stock solution was prepared by dissolving 0.1g of HMX into 5ml of acetonitrile (0.02 g HMX/ml).

All stock solutions were transferred to amber glass bottles with Teflon lined septum screw caps that were stored at room temperature. A 10 µL syringe was used to deliver 5 µl aliquots of the stock solutions. The 5 µl aliquot was allowed to dry before another was added to the coupon. If

FINAL

the aliquots had not been allowed to dry then the solution would have run off the surface and analyte (i.e., TNT, RDX, HMX) would have been lost. It took less than 1/2 a minute for the solvent to evaporate. Coupons were spiked in batches, so that each coupon in the batch was treated with a single aliquot (analyte) prior to adding another aliquot of stock solution.

Once spiked the coupons could be placed within chambers. These chambers were to protect the spiked coupons and the range scrap. Chambers for housing the coupons and range scraps were made from standard zinc plated steel electrical switch boxes. These boxes had four 4.7mm holes in the bottom, and had an additional 4.7mm hole drilled into each of the four side walls. Zinc coated wire fencing (6.4mm by 6.4mm) was molded into platforms to hold the coupons and range scrap fragments firmly near the center of the chamber. The chamber and wire mesh cage was not physically deformed when exposed to a thermal treatment of 1100 °F for a six hour period. However, this thermal treatment did turn the zinc plating to white or yellowish color and in some places, especially along the edges, the plating became friable.

Locations. For clarity, the actual spiked coupon locations per trial are included in the results section with the data.

Coupon Collection. Following HGD trial, all twelve of the chambers containing the spiked coupons were retrieved once the pile had cooled to ambient temperature. The chambers and a chamber which served as a trip blank (contained a spiked and unspiked coupon) were taken to an on-site laboratory where the coupons and pieces of range scrap were submersed in acetone for extraction, in preparation for analysis. Clean metal tweezers were used to transfer each coupon and piece of range scrap from the chambers to an extraction vial. Each chamber placed in the treatment pile contained a quality assurance (QA) coupon and three of the 12 chambers also contained a piece of contaminated range scrap (fragment of a low-order hand grenade), therefore, some 16 extraction vials were used for each trial.

Analysis. Reverse phase - high-performance liquid chromatography - ultraviolet (RP-HPLC-UV) determinations were performed on two different modular systems. Pre-trial samples and coupons and range scrap from the first two HGD trials were analyzed on a system composed of a Spectra-Physics Model SP8800 ternary HPLC pump, a Spectra-Physics 100 variable wavelength UV detector set at 254nm, a Dynatech Model LC241 auto sampler with a 100µl injection loop, and a Hewlett Packard 3396A digital integrator was used. A second round of pre-trial samples, treated range scrap, and coupon and range scrap from the third through seven trials were analyzed with the following system; a Spectra-Physics Model SP8800 ternary HPLC pump, a Spectra-Physics SP8490 variable wavelength UV detector set at 254nm, a Spectra-Physics SP8875 auto sampler, and a Hewlett-Packard 3396A digital integrator. With the second system an injection volume of 20µl was used for trials three through six. Trial seven used an injection volume of 100µl.

The QA coupons and range scraps were extracted with 10ml of acetonitrile in a cooled sonic bath for an 18-hour period. On-site pre and post range scrap pile samples were taken using acetone moistened wipes and by removing small pieces of material. In preparation for analysis, sample extracts and analytical standards were diluted with deionized water (0.3ml of acetonitrile extract with 1.2ml of water). On both RP-HPLC-UV systems sample analysis was performed on a 15cm by 3.9cm (4µm) NovaPak C-8 column (Waters) eluted with a 85/15 water/isopropanol (v/v) at 1.4 ml/min. Concentrations were estimated against a Method 8330 calibration standard purchased from Restek.

QUALITY ASSURANCE/QUALITY CONTROL FOR SPIKED COUPONS

Experimental Control. Spiked coupons from each preparation batch and representative pieces of range scrap were extracted and analyzed without exposure to the HGD treatment, ensuring the target spike concentration was on the coupons and to determine whether target explosives were on the selected pieces of range scrap.

4.3.2 Emissions Monitoring.

Instrumentation Plan. The instrumentation plan for this test was designed to provide data on the emissions associated with Hot Gas Decontamination. A description of the instrumentation is provided below and a schematic of the instrumentation setup is presented as Figure 4.3-2. Figures 4.3-3 through 4.3-6 are photographs of the instrumentation setup.

The sampling and analysis methodologies for this test were chosen because of their relevance to expected emission products from the Hot Gas Decontamination, specific environmental contamination concerns, and completeness. A summary of the sampling and analytical methodologies is provided in Table 4.3-1. Several complete lists of target analytes are shown in Tables 4.3-2 through 4.3-7. For additional details of the test, see the Final Demonstration Plan¹⁷ (Appendix B)

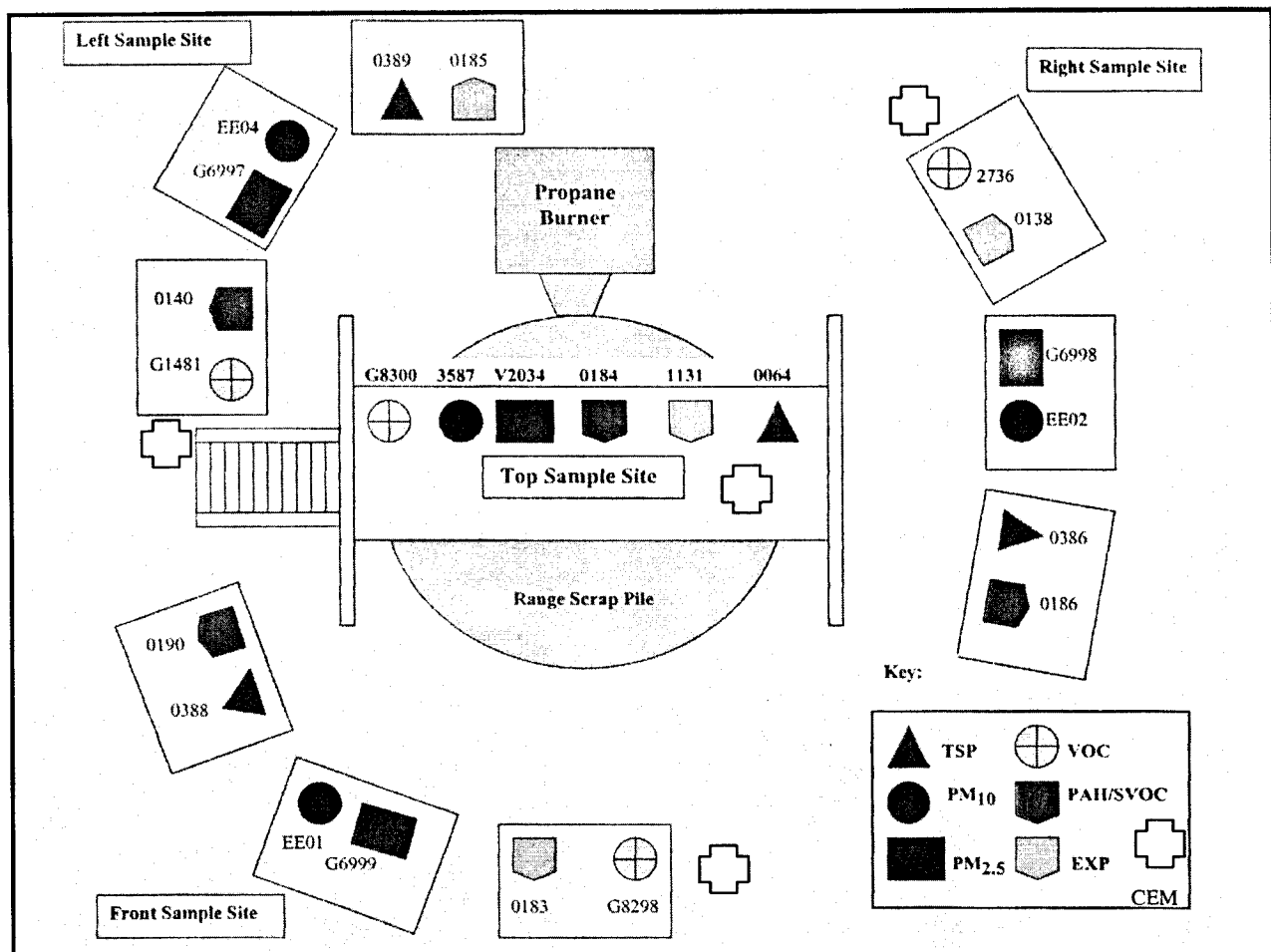


Figure 4.3-2. Location of Emission Samplers in comparison to Range Scrap Pile



Figure 4.3-3. Samplers Located in Front of the Burner (Front Site).

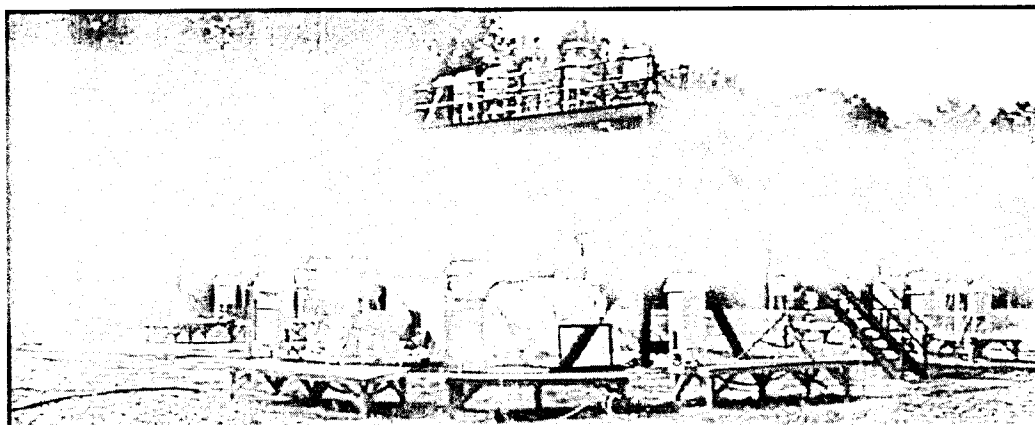


Figure 4.3-4. Samplers Located Left of the Burner (Left Site).

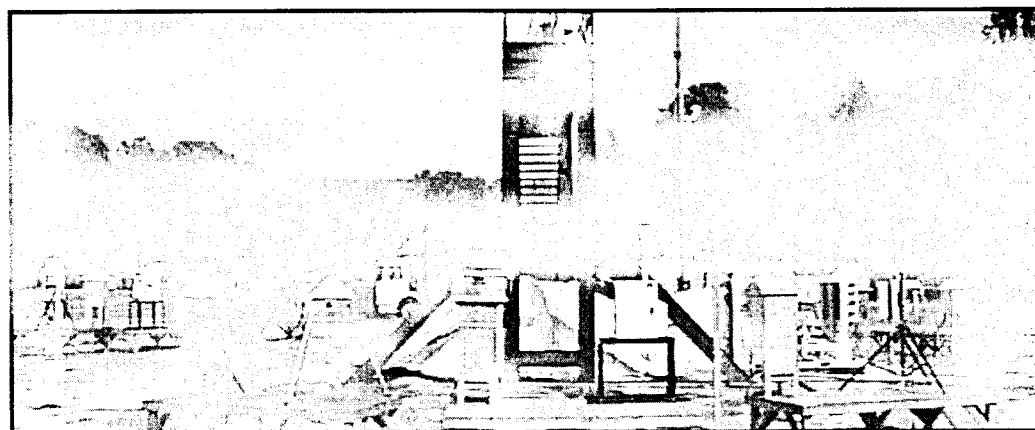


Figure 4.3-5. Samplers Located Right of the Burner (Right Site).

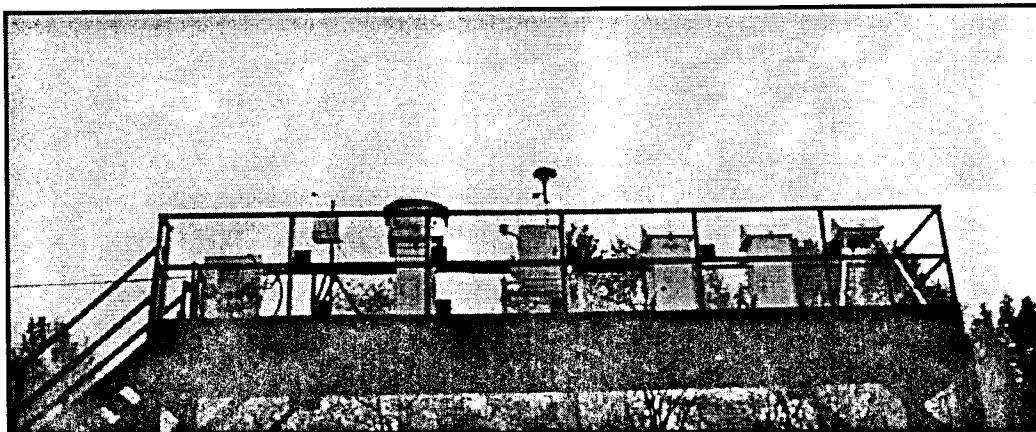


Figure 4.3-6. Samplers Located Above the Burner (Top Site).

Table 4.3-1. Sampling and Analysis Methodology for HGD

Analytical Target	Sampling Equipment	Sampling Method	Analytical Method
CO, CO ₂ , NO _x , SO ₂	Continuous sampling analyzer	40 CFR 60 Appendix A Method 3A, 6C, and 7E	40 CFR 60 Appendix A Method 3A, 6C, 7E, and 10
VOCs	Evacuated silicon-lined canisters	EPA Method TO-14A	EPA Method TO-14A
PAHs	High-volume ambient air sampler (filter and XAD-2 resin)	EPA Method TO-13A	ASTM D6209-98
SVOCs	High-volume ambient air sampler (filter and XAD-2 resin)	EPA Method TO-13A	ASTM D6209-98
Energetic and explosives materials	High-volume ambient air sampler (filter and XAD-2 resin)	EPA Method TO-13A	USACHPPM SOP CAD 26.2

FINAL

Metals/TSP	Quartz particulate filter	TSP, 40 CFR 50 Appendix B	40 CFR 50 Appendix G, modified, USEPA Method 200.7, and USEPA Method 245.1 (Mercury)
PM ₁₀	Quartz particulate filter	EPA Method IO-2.1	USACHPPM - AAQMP, Large Filter Weighing Technical Guidance
PM _{2.5}	Quartz particulate filter	40 CFR Part 53	USACHPPM - AAQMP, Small Filter Weighing Technical Guidance

SAMPLE COLLECTION AND ANALYSIS FOR EMISSIONS MONITORING

CEMs. Continuous Emissions Monitoring was conducted according to Title 40 Code of Federal Regulations (CFR) 60, Appendix A, Methods 3A, 6C, and 7E. Analysis was performed according to Title 40 Code of CFR 60, Appendix A, Methods 3A, 6C, 7E, and 10.

Representative air samples from test piles were obtained by drawing air through four discrete sampling lines located at various points around each test pile. Sampling lines were made of $\frac{3}{8}$ " 316 stainless steel tubing and $\frac{3}{8}$ " Teflon sample line (stainless steel will be used near the test pile to reduce the possibility of melting). The individual sample lines were the same length, and ran to a primary Teflon manifold. A Teflon pump was used to pull the air sample from around the test piles and into the primary manifold at a flow rate of approximately 14 liters per minute. The sample lines that interfaced to the primary manifold were the same lengths so that the sample flow from each of the sampling points was equal. The combined air sample was pumped through Teflon tubing to a secondary Teflon manifold contained in the instrumentation trailer with the analyzers located approximately 100 feet from the pile. Continuous emissions monitoring was performed using continuous gas analyzers. Thermo Environmental Inc., model numbers 41C and 48C nondispersive infrared analyzers were used to detect and quantify carbon dioxide (CO₂) and carbon monoxide (CO) respectively. A Thermo Environmental Instruments Inc., model 42C, chemiluminescence analyzer was used to detect and quantify oxides of nitrogen (NO_x), and a Thermo Environmental Instruments Inc., model 43C, pulsed fluorescence analyzers was used for sulfur dioxide (SO₂) detection. Each of the continuous gas analyzers contained a pump with a precision flow meter used to extract the sample gas from the secondary manifold. The sample streams were not diluted because low-level emissions were expected. The gas was sampled from above the pile and three additional locations from around the pile. After direct analyzer calibration, a NIST traceable gas standard was introduced to the end of the sample line. A $\pm 5\%$ sampling system bias was observed. All results were recorded. Samples were collected at a rate of one data point every 6 seconds (using 6 second averaging times on the analyzers) by a personal computer equipped with a National Instruments Data Acquisition module and Lab View software. Each test was assigned a unique test number. The raw data was stored on the hard drive of the personal computer. A maximum of 24 hours of continuous sampling was required for trials one, two, and six.

FINAL

VOCs. The VOC samples were collected and analyzed according to USEPA Compendium Method TO-14A, Determination of Volatile Organic Compounds in Ambient Air Using Specially Prepared Canisters with Subsequent Analysis by Gas Chromatography²⁰. The canisters were specially lined with silicon to mitigate VOCs from interacting with the stainless steel. Prior to sampling, each canister was certified clean and evacuated to near-zero absolute pressure by the laboratory. Two types of samplers were used for to pressurize the canisters, the Xontech Samplers and the Ambient Volatile Organic Collection System (AVOCS) samplers (CHPPM Report²⁷ pg.14, Appendix B of this report). All samples were collected for a 24-hour test period. The standard list of both polar and non-polar VOCs as determined by Method TO-14A were analyzed. The laboratory followed their in-house SOP for analyzing the canisters, pursuant TO-14A requirements. Concentrations of the VOC compounds were reported in parts per billion volume (PPB).

PAHs and SVOCs. The PAHs were collected according to Compendium Method TO-13A, Determination of Polycyclic Aromatic Hydrocarbons in Ambient Air Using Gas Chromatography/Mass Spectrometry (GC/MS)²¹. Analysis was performed according to the Standard Test Method for the Determination of Gaseous and Particulate Polycyclic Aromatic Hydrocarbons in Ambient Air (Collection on Sorbent-Backed Filters with Gas Chromatographic/Mass Spectrometric Analysis), American Society for Testing and Materials (ASTM) D6209-98²². The USACHPPM sampling team used Tisch Environmental Model 5007, high-volume samplers to collect PAH samples for this study. This sampler operated by drawing air into a covered housing through a 105-millimeter quartz fiber filter and then through an XAD-2 resin adsorbent cartridge. The filter trapped particulates and the XAD-2 resin collected the vapor phase of the PAHs that were present in the air. Since PAH compounds may be present in the form of particulate and/or vapor, both the filter and the XAD-2 resin were combined and analyzed for the target compounds. The concentrations of the PAHs were determined by dividing the mass of each compound by the volume of air drawn through the cartridge during the sampling period. The SVOCs were collected according to the same method as the PAHs, however, the ASTM D6209-98 method has not been validated for SVOCs. The laboratory developed an analysis method applicable as a screening procedure for SVOCs. This analysis method was used during this sample event to estimate the concentration of SVOCs.

Energetic and Explosive Compounds. Energetic and explosive compounds were collected according to Compendium Method TO-13A, Determination of PAHs in Ambient Air Using GC/MS²¹. Analysis was performed according to the procedures outlined in USACHPPM, Directorate of Laboratory Sciences, Chromatographic Analysis Division, Procedure for Analysis of Explosives in Air²², SOP CAD 26.2, November 2000. This method specifically addresses the extraction and analysis of 20 explosives and related compounds of interest from air by XAD-2 resin and filter sampling followed by isoamyl acetate extraction. A Gas Chromatograph/Electron Capture Detector was used to analyze for nitroaromatics, nitramines, and PETN. A GC/MS was used to analyze for diphenylamine (DPA), dibutylphthalate (DBP), and dioctylphthalate (DOP). A Tisch Environmental Model 5007 high-volume sampler was used to collect energetic and explosive compound samples for this study. This sampler operated by drawing air into a covered housing through a 105-millimeter quartz fiber filter and then through an XAD-2 resin adsorbent cartridge. The filter trapped particulates and the XAD-2 resin collected the vapor phase of energetic and explosive compounds that were present in the air. Since energetic and explosive compounds could have been present in the form of particulate as well as vapor, both the filter and the XAD-2 resin were combined for analysis. The concentration of the energetic and

FINAL

explosive compounds were determined by dividing the mass of each compound by the volume of air drawn through the cartridge during the sampling period.

Metals and Total Suspended Particulate. Metals were not necessarily suspected in the emissions but were included for screening purposes. All metal samples were collected according to Title 40, Code of Federal Regulations (CFR) 50, Appendix B, Reference Method for the Determination of Suspended Particulate Matter in the Atmosphere (High-Volume Method)²⁴. The sampling team used the Graseby-Andersen Model GT2200 high-volume TSP sampler to sample for metal analytes. The TSP sampler operated by drawing ambient air into a covered housing and through a quartz fiber filter. Metal samples were prepared according to 40 CFR 50, Appendix G, and all metals were determined by USEPA Method 200.7 (Inductively Coupled Plasma-atomic Emission Spectrometry) except for Mercury, which was determined using USEPA Method 245.1. The concentrations of the metal analytes were determined by dividing the mass of each analyte by the volume of air drawn through the filter during the sampling period, which was 24 hours.

PM₁₀. All PM₁₀ samples were collected using Graseby PM₁₀ samplers with volumetric flow controllers (VFC) in accordance with USEPA Compendium Method IO-2.1, Sampling of Ambient Air for Total Suspended Particulate Matter (SPM) and PM₁₀ Using High Volume (HV) Sampler²⁵. The PM₁₀ sampler operates by drawing ambient air into the PM₁₀ inlet, which used the particulate aerodynamic properties to separate the larger particulate from the 10 micron and smaller diameter particulate (PM₁₀). The PM₁₀ fraction was then collected on a quartz fiber filter. The concentration was determined gravimetrically, with the filter weighed before and after sampling. The calculated volume of air drawn through the filter was divided into the weight difference between the initial and final filter weights. This quotient was reported as the concentration of PM₁₀ during that sample period. The sampling period was the standard 24-hour period used for ambient sampling.

PM_{2.5}. Ambient air monitoring was conducted for PM_{2.5} by using the Rupprecht & Patashnick Co., Inc. Partisol[®] -FRM Model 2000 PM_{2.5} Air Samplers²⁶. These samplers were designed to conform to the USEPA Federal Reference Method for fine particulate sampling as designated in 40 CFR Part 53. Each sampler was equipped with a PM₁₀ (1st stage) inlet at the entrance of the sample stream to provide a 10µm precut particle size and to protect the sample path against precipitation. An USEPA designed PM_{2.5} WINS Impactor performed a 2.5µm cut of the incoming particulate matter after passing through the PM₁₀ inlet and before the sampling stream passes through a 47-mm filter. The temperature of the sample filter does not deviate by more than 5° C from the ambient air temperature because of a continuous compartment ventilation system. The sampler is designed to sample at 16.7 liters/minute for a 24-hr sample interval to conform to USEPA requirements. Samplers were set-up and operated for 24 hours. The filters were gravimetrically weighed in a climate-controlled laboratory before and after the survey to determine the mass of the PM_{2.5} collected on the samples. The internal computer calculated the volume of air passing through the filter. Concentrations were derived by dividing the PM_{2.5} mass by the volume of air passing through the filter. All filters were conditioned prior to weighing per USEPA guidance. All filters were weighed and conditioned in a CHPPM dedicated weighing chamber, which was conditioned to EPA guidelines for all criteria including temperature and humidity. All microbalances were calibrated to USEPA standards.

¹ Partisol is a registered trademark of Airmetrics Rupprecht & Patashnick Co., Inc., Albany NY

FINAL

QUALITY ASSURANCE/QUALITY CONTROL FOR EMISSIONS MONITORING

CEMs

Equipment Calibration. Thermo Environmental Inc., model numbers 41C, 42C, 43C, and 48C were calibrated according to the procedures outlined by the individual instrument manufacturer. Analyzers were powered up a minimum of two hours (four hours preferred) prior to calibration and checkout procedures in order to assure warm up. A single-point calibration was conducted using Nitrogen (N₂) as a zero gas and a calibration gas equal to 80% of the full scale of the individual analyzer. This calibration standard is traceable to NIST standards (certification on file in maintenance shop). A data acquisition system was used to record the outputs for zero and the span. The calibration factor was then calculated based on the span value entered for the calibration gas. This data acquisition system also measures noise and drift for both baseline and span. Calibrations of all analyzers were checked before testing.

Sample Preservation. A Mine Safety Appliance ultra-type H cartridge filter was used on the end of each polyethylene sample line for particulate control. An in-line Balston 95S6 filter was used to trap any condensation.

Sample Validation Criteria. All repairs were conducted according to manufacturer's specifications and with authorized replacement parts. Linearization checks were conducted periodically according to manufacturer's recommendations. Other maintenance and adjustments were conducted as required by the checkout procedures. Maintenance records were maintained documenting all work done on each analyzer. All equipment used to repair and maintain the analyzers were calibrated as required.

VOCs

Equipment Calibration

Xontech Sampler. The mass flow sensor located inside each Xontech sampler was calibrated against a National Institute of Standards and Technology (NIST) traceable flow meter to ensure proper flow. During each sample event, the sample canisters were shaded from direct sunlight (which would have affected the volume of collected air due to a changing temperature) and the flow rates were checked and recorded before and after each sampling event to ensure that the desired volume of sample was collected.

AVOCS Sampler. The pressure and mass flow sensors located inside the AVOCS were calibrated against a NIST traceable pressure meter and a NIST traceable flow meter to ensure proper pressure and flow readings. Prior to sampling, an internal cleaning cycle was performed on each AVOCS sampler. Contamination was baked off by an internal heater set at 50°C during the cleaning cycle and then exhausted from the sampler. During a sample event, the sample canisters were shaded from direct sunlight (which would have affected the volume of collected air due to a changing temperature) and the flow rates were checked and recorded before and after each sampling event to ensure that the desired volume of sample was collected.

Sample Preservation. Prior to and after sampling, all canisters were stored in the mobile laboratory at ambient room temperature. The samples were then hand-carried by the AQSP sampling team the USACHPPM Laboratory. Canisters were then sent to Lancaster Laboratories and analyzed within 30 days of sampling.

FINAL

Sample Validation Criteria. The sampling and analytical equipment, dilution gases, and canisters were certified clean to less than 0.2 ppb prior to use. Prior to and after each sampling event, the canister vacuum was measured and recorded on the identification tag on each canister. Upon return to the laboratory, the canister vacuum was again recorded. A loss of canister vacuum was not detected prior to sampling or prior to laboratory analysis. Initial and final pressure checks served to indicate whether a canister leak had occurred. For quality assurance purposes, all initial pressures read between -30 and -29 in Hg. The sampler flow rates were checked before and after sampling and varied by less than 4%. During analysis, a 4-bromofluorobenzene tuning check was evaluated at least every 24 hours.

PAHs and SVOCs

Equipment Calibration. The Tisch Environmental high-volume sampler was calibrated according to USEPA Compendium Method TO-13A standards at Bldg. 600 prior to set up at the sampling sites. Calibration sheets are located in Appendix B of the CHPPM Report²⁷ (presented in Appendix B of this report). An orifice standard was used to calibrate the magnehelic gauge. All sampler regression values were within tolerances. Flow checks were performed during each sample event by confirming the magnehelic gauge reading.

Sample Preservation. The XAD-2 resin cartridges were wrapped in aluminum foil and stored in separate glass containers. The aluminum foil provided protection from sunlight since the XAD-2 resin is photoreactive. Each glass cartridge was packed in Teflon containers to protect the integrity of the glass during transportation. After each sampling event, each sample cartridge was rewrapped in aluminum foil and stored in the same sealed Teflon container. Samples were then taken to the mobile laboratory and stored in the laboratory refrigerator. These samples were then hand-carried by the AQSP sample team to the USACHPPM laboratory. Several ice packs were added to the cooler to ensure that temperatures remained below 4 °C.

Sample Validation Criteria. All sample collection cartridges were cleaned, prepared, and certified for use per USEPA Compendium Method TO-13A. All sample run times were within one hour of the required 24-hour sample duration. All flow volumes were within the method specific range of 100 m³ - 325 m³. All calibration criteria were met, to include that no single point flow check was greater than $\pm 4\%$ deviation and sampler regression coefficients were greater than 0.99. Storage temperatures were less than 4 °C when samples arrived at the laboratory. Extraction was performed within seven days of sampling and analysis was performed within 40 days of extraction. Field data sheets for PAHs are located in Appendix C of CHPPM Report²⁷ (presented in Appendix B of this report).

Energetic and Explosive Compounds

Equipment Calibration. The high-volume samplers were calibrated in Building 600 prior to set up at Air Base Range 9. An orifice standard was used to calibrate the magnehelic gauge. The pressure differential between the cartridge opening and the motor exhaust was then set to a gauge reading of 15 inches of water. Flow checks were performed during each sample event by confirming the magnehelic gauge reading. If the gauge did not read 15 inches of water, the restrictor neck was adjusted until the desired flow was reached. The results of the calibration and flow checks were recorded on field data sheets, which are contained in Appendix C of CHPPM Report²⁷ (presented in Appendix B of this report).

FINAL

Sample Preservation. The XAD-2 resin cartridges were wrapped in aluminum foil and stored in separate glass containers. The aluminum foil provided protection from sunlight since the XAD-2 resin is photoreactive. Each glass cartridge was packed in Teflon containers to protect the integrity of the glass during transportation. After each sampling event, each sample cartridge was rewrapped in aluminum foil and stored in the same sealed Teflon container. Samples were then taken to the mobile laboratory and stored in the laboratory refrigerator. These samples were then hand-carried by the AQSP sample team to the USACHPPM laboratory. Several ice packs were added to the cooler to ensure that temperatures were less than 4 °C.

Sample Validation Criteria. All sample collection cartridges were cleaned, prepared, and certified for use per USEPA Compendium Method TO-13A. All sample run times were within one hour of the required 24-hour sample duration. All flow volumes were within the method specific range of 100 m³ - 325 m³. All calibration criteria were met, to include that no single point flow check was greater than ± 4% deviation and sampler regression coefficients were greater than 0.99. Storage temperatures were less than 4 °C when samples arrived at the laboratory. Extraction was performed within seven days of sampling and analyzed within 40 days of extraction. Field data sheets for PAHs are located in Appendix C of CHPPM Report²⁷ (presented in Appendix B of this report).

Metals and Total Suspended Particulate

Equipment Calibration. The high-volume TSP samplers were calibrated and checked for leaks at the staging area prior to set up at the sample sites. A calibrated orifice transfer standard kit, traceable to NIST, was used to calculate each sampler's flow parameters. Calibration of the four high-volume samplers yielded acceptable correlation coefficients greater than 0.990, as required by 40 CFR Part 50, Appendix B (see Appendix B of CHPPM Report²⁷, presented in Appendix B of this report). Flow checks were performed at the beginning and end of each sampling event to ensure proper equipment operation. Periodic flow checks during sampling events were also performed. Valid samples had flow rates between 1.1 and 1.7 m³/min, and a total sample time of 24 hrs (±1 hr). The results of the flow checks were entered on TSP field data sheets (see Appendix C of CHPPM Report²⁷, presented in Appendix B of this report).

Sample Preservation. Prior to field use, all quartz fiber filters were visually inspected for tears and pinholes. Each filter was then desiccated for 24 hours, weighed and then placed in individual, protective filter envelopes. While at APG, all filters were maintained in protective filter envelopes and stored in the mobile field laboratory. At the conclusion of the ambient air sampling mission, all filters were hand-carried by the ambient air sampling team back to USACHPPM. Filters were then weighed by the AQSP and then analyzed by the ATC laboratory for metals.

Sample Validation Criteria. All sample run times were within one hour of the required 24-hour sample duration as well as the flow rate of 1.1 - 1.7 m³/min. All calibration criteria were met, including that no single point flow check was greater than ± 10% deviation and sampler regression coefficients were greater than 0.99.

PM₁₀

Equipment Calibration. The PM₁₀ samplers were calibrated according to guidance outlined in Section 2.11, Reference Method for the Determination of Particulate Matter as PM₁₀ in the

FINAL

Table 4.3-3. TO-14 VOCs Extended Target Analyte List

Propene	1,1-Dichloroethane	Tetrachloroethene
Dichlorodifluoromethane	Vinyl acetate	2-Hexanone
Chlorodifluoromethane	cis-1,2-Dichloroethene	Dibromochloromethane
Freon 114	2-Butanone	1,2-Dibromoethane
Chloromethane	Ethyl acetate	Chlorobenzene
Vinyl chloride	Methyl acrylate	1,1,1,2-Tetrachloroethane
1,3-Butadiene	Chloroform	Ethylbenzene
Bromomethane	1,1,1-Trichloroethane	m/p-Xylene
Chloroethane	Carbon tetrachloride	o-Xylene
Dichlorofluoromethane	1,2-Dichloroethane	Styrene
Trichlorofluoromethane	Benzene	Bromoform
Pentane	Iso-octane	Cumene
Acrolein	Heptane	1,1,2,2-Tetrachlorethane
1,1-Dichloroethene	Trichloroethane	1,2,3-Trichloropropane
Freon 113	Ethyl acrylate	Bromobenzene
Acetone	1,2-Dichloropropane	4-Ethyltoluene
Methyl iodide	Methyl methacrylate	1,3,5-Trimethylbenzene
Carbon disulfide	Dibromomethane	Alpha methyl styrene
Acetonitrile	1,4-Dioxane	1,2,4-Trimethylbenzene
3-Chloropropene	Bromodichloromethane	1,3-Dichlorobenzene
Methylene chloride	4-Methyl-2-pentanone	1,4-Dichlorobenzene
tert-Butyl alcohol	Toluene	Benzyl chloride
Acrylonitrile	Octane	1,2-Dichlorobenzene
trans-1,2-Dichloroethene	trans-1,3-Dichloropropene	Hexachlorethane
Methyl t-butyl ether	Ethyl methacrylate	1,2,4-Trichlorobenzene
Hexane	1,1,2-Trichloroethane	Hexachlorobutadiene

FINAL

Table 4.3-4. TO-13 PAHS Target Analyte List

Naphthalene	Fluoranthene	Benzo(e)pyrene
Acenaphthylene	Pyrene	Benzo(a)pyrene
Acenaphthene	Benzo(a)anthracene	Indeno(1,2,3-cd)pyrene
Fluorene	Chrysene	Dibenz(a,h)anthracene
Phenanthrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene
Anthracene	Benzo(k)fluoranthene	

Table 4.3-5. Energetics and Explosives Target Analyte List

Nitrobenzene	2,4,6-Trinitrotoluene
2-Nitrotoluene	RDX (Hexahydro-1,3,5-trinitro-1,3,5-triazine)
3-Nitrotoluene	4-Amino-2,6-dinitrotoluene
4-Nitrotoluene	2-Amino-4,6-dinitrotoluene
Nitroglycerine	Tetryl
1,3-Dinitrobenzene	HMX (1,3,5,7-Tetranitro-1,3,5,7-tetrazacyclooctane)
2,6-Dinitrotoluene	PETN (Pentaerythritol tetranitrate)
2,4-Dinitrotoluene	DPA (Diphenylamine)
1,3,5-Trinitrobenzene	DBP (Dibutylphthalate)

Table 4.3-6. Metals Target Analyte List

Aluminum	Chromium	Nickel
Antimony	Cobalt	Selenium
Arsenic	Copper	Silver
Barium	Lead	Thallium
Beryllium	Magnesium	Vanadium
Cadmium	Manganese	Zinc
Calcium	Mercury	

Table 4.3-7. SVOCS (8270 List) Target Analyte List

N-Nitrosodimethylamine	Hexachlorobutadiene	N-Nitrosodiphenylamine
Bis(2-chloroethyl)ether	4-Chloro-3-methylphenol	4-Bromophenyl-phenylether
Phenol	2-Methylnaphthalene	Hexachlorobenzene
2-Chlorophenol	Hexachlorocyclopentadiene	Pentachlorophenol
1,3-Dichlorobenzene	2,4,6-Trichlorophenol	Phenanthrene
1,4-Dichlorobenzene	2,4,5-Trichlorophenol	Anthracene
1,2-Dichlorobenzene	2-Chloronaphthalene	di-n-Butylphthalate
Benzyl alcohol	2-Nitroaniline	Fluoranthene
Bis(2-chloroisopropyl)ether	Acenaphthylene	Pyrene
2-Methylphenol	Dimethylphthalate	Butylbenzylphthalate
Hexachloroethane	2,6-Dinitrotoluene	Benzo(A)anthracene
N-Nitroso-di-n-propylamine	Acenaphthene	Chrysene
4-Methylphenol	3-Nitroaniline	3,3-dichlorobenzidine
Nitrobenzene	2,4-Dinitrophenol	Bis(2-ethylhexyl)phthalate
Isophorone	Dibenzofuran	di-n-Octylphthalate
2-Nitrophenol	2,4-Dinitrotoluene	Benzo(b)fluoranthene
2,4-Dimethylphenol	4-Nitrophenol	Benzo(k)fluoranthene
Bis(2-chloroethoxy)methane	Fluorene	Benzo(a)pyrene
2,4-Dichlorophenol	4-chlorophenyl-phenylether	Indeno(1,2,3-cd)pyrene
1,2,4-Trichlorobenzene	Diethylphthalate	Dibenz(a,h)anthracene
Naphthalene	4-Nitroaniline	Benzo(g,h,i)perylene
4-Chloroaniline	4,6-Dinitro-2-methylphenol	

4.4 PRE-TEST BACKGROUND SOIL SAMPLES

To establish a baseline of comparison for the performance assessment, several types of sample matrices and chemical analyses were undertaken prior to the HGD operation and demonstration test. Soil samples of the ground underneath the demonstration site, samples of range scrap, and ambient air were monitored to establish the baseline. Further discussion of the analyses is as follows.

Soil Samples: For baseline and comparison purposes, two one-kg replicate composite soil samples was collected before the demonstration. Samples were collected from the interior diameter of the pile site.

FINAL

Sample Collection: To test for a potential impact of HGD treatment on the soil surface under the scrap pile, two composite soil samples (approximately 1 kg each) were collected before the demonstration. The samples were properly stored in containers at room temperature (25°C) until they were processed. Each composite sample is comprised of 50 units, with each unit weighing approximately 20 g. These units were randomly collected over the entire area covered by the Hot Gas Decontamination (HGD) treatment system. The composite samples were air-dried, sieved (10 mesh), and then thoroughly mixed. In order to obtain representative subsamples for analysis, each composite sample is spread out on a clean flat surface and 30 random increments, were obtained without differentiating between the sizes of the particles. This homogenized sample was split into two samples, one for metal analysis and the other for explosive analysis.

Soil Analysis - Metals: Three duplicates of the homogenized sample were digested in accordance with EPA Method 3051, "Microwave Assisted Acid Digestion of Sediments, Sludges, Soils, and Oils". Therefore, there would be three values for the composite sample that are averaged to achieve a mean value, which is representative of the entire exposed area before the HGD demonstration. In addition to the duplicates, a laboratory soil standard, laboratory soil sample duplicate, and a reagent blank were digested in accordance to EPA Method 3051.

All digested samples were analyzed in accordance to EPA Method 6010B, "Inductively Coupled Plasma-Atomic Emission Spectrometry", and EPA Method 6020, "Inductively Coupled Plasma-Mass Spectrometry". The metals analyzed for in soil samples are presented in Table 4.4-1.

Table 4.4-1. List of Metals for Soil Samples

Element	Symbol	Element	Symbol
Aluminum	Al	Magnesium	Mg
Antimony	Sb	Manganese	Mn
Arsenic	As	Mercury	Hg
Barium	Ba	Molybdenum	Mo
Beryllium	Be	Nickel	Ni
Boron	B	Potassium	K
Cadmium	Cd	Selenium	Se
Calcium	Ca	Silver	Ag
Chromium	Cr	Sodium	Na
Cobalt	Co	Strontium	Sr
Copper	Cu	Thallium	Tl
Iron	Fe	Vanadium	V
Lead	Pb	Zinc	Zn

FINAL

The Perkin-Elmer Plasma Inductively Coupled Plasma (ICP) Spectrometer, model 3000 Dual View, and the Perkin Elmer Plasma Inductively Coupled Plasma Mass Spectrometer (ICP-MS), model Elan 5000, were used to perform the metal analysis. The instruments were calibrated as followed:

- Varied serial dilutions ranging from 100.00 to 2000.00 µg/l standards on the ICP, and
- Varied serial dilutions ranging from 20.00 to 100.00 µg/l standards on the ICP-MS.

Initially all requested metals were analyzed on the ICP, but the ICP data for Strontium (Sr), Thallium (Tl), and Vanadium (V) produced less than expected quality control recoveries that required these metals to be analyzed on the ICP-MS. The low level readings of the ICP-MS produced better quality control recoveries for these metals that were within the recovery ranges stated in the HGD test plan.

The quality control report contains an Instrument Spike, a 1:5 Dilution, and a Matrix Duplicate (MD) of the soil sample. All were within QC requirements for all elements as stipulated in the test plan with the following exceptions:

- The Aluminum (Al) and Iron (Fe) spike recoveries were both above the +/-25% limit. The initial concentrations of both elements exceeded the calibration curve by least 68% therefore producing spike recoveries out of the +/-25% range.
- The 33.33 Relative Percent Difference (RPD) for Zinc (Zn) in the Matrix Duplicate table exceeds the +/-20% limit.

A Laboratory Performance Check (LPC) and a Matrix Duplicate (MD) were used to meet the QC requirements for sample preparation, which is recorded in Section F, "Quality Report Summary" of the ATC Chemistry Lab Report located in Appendix B of this report. All were within QC requirements of +/- 30% for all elements with the exception of Beryllium (Be) and Thallium (Tl), which are 5.47% and 0.88% above the limit.

The reporting unit for the sample is in mg/Kg. The final reporting values were computed as follows:

$$\text{mg/Kg} = \text{mg/L} * 0.100 \text{ L /dry weight of sample(Kg)}$$

Sample Analysis - Explosive Concentrations. The soil sample was approximately 100 g in size and placed into pre-cleaned jar. The soil sample was air-dried, then ground with a mortar and pestle and sieved through a 30-mesh screen. A two-gram sample was then taken from the 100 grams. The two-gram sample was placed in a clean vial and 10 mL of extraction fluid (acetonitrile) was added. The sample was extracted for 18 hours in a cooled ultrasonic bath. The extract was then filtered and placed in a high-performance liquid chromatography (HPLC) auto sampler vial. The HPLC analysis using EPA Method 8330 titled, "Determination Of Concentration of Nitroaromatics and Nitramines By High-Performance Liquid Chromatography" was performed with an ultraviolet (UV) 254-mm detector that has quantitative limits of about 1 mg/kg (or µg/g) for TNT and RDX and about 2 mg/kg for HMX.

FINAL

5.0 Performance Assessment

Seven tests of the transportable Hot Gas decontamination system were conducted from 16 August 2001 through 24 October 2001. The specific dates and times for the seven tests are as follows.

Test No.	Start Date and Time
1	8/16/01 14:56
2	9/5/01 10:36
3	9/18/01 13:57
4	9/28/01 9:43
5	10/4/01 10:02
6	10/16/01 9:40
7	10/24/01 12:10

5.1 BURNER AND EQUIPMENT PERFORMANCE DATA AND ASSESSMENT

The data acquisition component of the instrumentation and control system collected performance data for temperature and time on each of the seven tests. The data was downloaded from the control system in Microsoft Excel format which was readily converted to graphic format.

For each of the seven demonstration tests, the data output and trend was graphed to show the performance of the system in terms of time, temperature, and distance from the burner. The graphs show time and temperature data from four perspectives as follows:

- System Heatup Performance – Elapsed Time vs. Temperature – shows the time for the coolest thermocouples to reach target temperature.
- Heatup Time Vs. Temperature for Hottest and Coolest Locations – shows temperatures versus elapsed time for individual thermocouples that were located in hottest locations (near the burner) and coolest locations (at outer reaches of pile farthest from the burner).
- Temperature Distribution versus Distance from Burner – Top of Pile – shows the temperature of the pile over a cross-section down the middle of the pile near the outer skin of the pile, presented at two-hour time intervals.
- Temperature Distribution versus Distance from Burner – Bottom Perimeter of Pile - shows the temperature of the pile along its outer perimeter at the bottom of the pile, presented at two-hour time intervals.

The graphic presentation of time and temperature data for each test are presented as follows.

FINAL

5.1.1 Test 1 Performance Data and Assessment

Test 1 was conducted on 16 August 2001 and was started late in the day at 14:56, due to first time setup and startup activities that took longer than expected. Test 1 was conducted on Pile 1, which was approximately 20.5 feet wide by 18 feet long by 7 feet high weighing approximately 14.5 tons of range residue.

The heat soak criteria for the burner system was set at 600 °F for 6 hours soak period for Test 1 in accordance with the test matrix of Final Demonstration Plan¹⁷ (Appendix B) Table 4.2-1. Test 1 was interrupted due to electric generator failure after 3 hours and 44 minutes. Due to the utility interruption, results for Test 1 are presented in only one graph, Figure 5.1-1, Test 1 Heatup Time vs. Temperature.

Test Preparation: Prior to testing on Pile #1, during the burner shake down test, two enclosure starter motor 8 amp fuses were noted blown. The two fuses (P/N F8329) were replaced. It was believed that the two fuses were blown as a result of excessive vibration during the transport of the burner from the manufacturer (Hauck®) to Aberdeen Test Center. Maintenance time was 0.5 of a man-hour.

In addition, during the burner shake down test, the range pressure switch was noted inoperative. An inspection revealed that water and condensation were inside the pressure switch. The range pressure switch was bypassed and testing was continued. 30 August 2001 the range pressure switch was replaced. Maintenance time was 0.5 of a man-hour.

Instrumentation-Thermocouples: Thermocouples with temperature transmitters were interlocked to the air heater fuel supply to control the programmed soak temperature of the scrap metal in the pile. The thermocouples were strategically placed at expected cooler locations (near the outside of the pile away from the burner). The actual locations of the thermocouples for Test 1 are shown in Figure 5.1-1.

Spiked Coupons: A total of 12 spiked coupons and three hand grenade fragments with explosive residues present on the surface were strategically located on and around the scrap pile and under the thermal blankets. The actual locations and analytical results are presented in Section 5.2.

Emissions Monitoring: Emissions monitoring was conducted during this for CO, CO₂, SO₂, NO_x, TSP, PM₁₀, and PM_{2.5}, VOC, SVOC, and PAH data as well as energetic analysis. The actual instrumentation, locations, sampling and analysis methods and results are presented in the Section 4.2 of this report.

Test Execution – Insulate Pile: The thermal blanket was installed over Pile #1. The thermal blanket was installed as follows: Approximately 320 ft² of stainless steel mesh was placed over the scrap closest to the propane heater outlet. Another length of stainless steel mesh that measured approximately 56 ft² was draped over the propane heater shroud. The remaining backside of pile was covered with approximately 400 ft² of overlapping carbon steel mesh. The mesh from the propane heater shroud to the first 1/3

FINAL

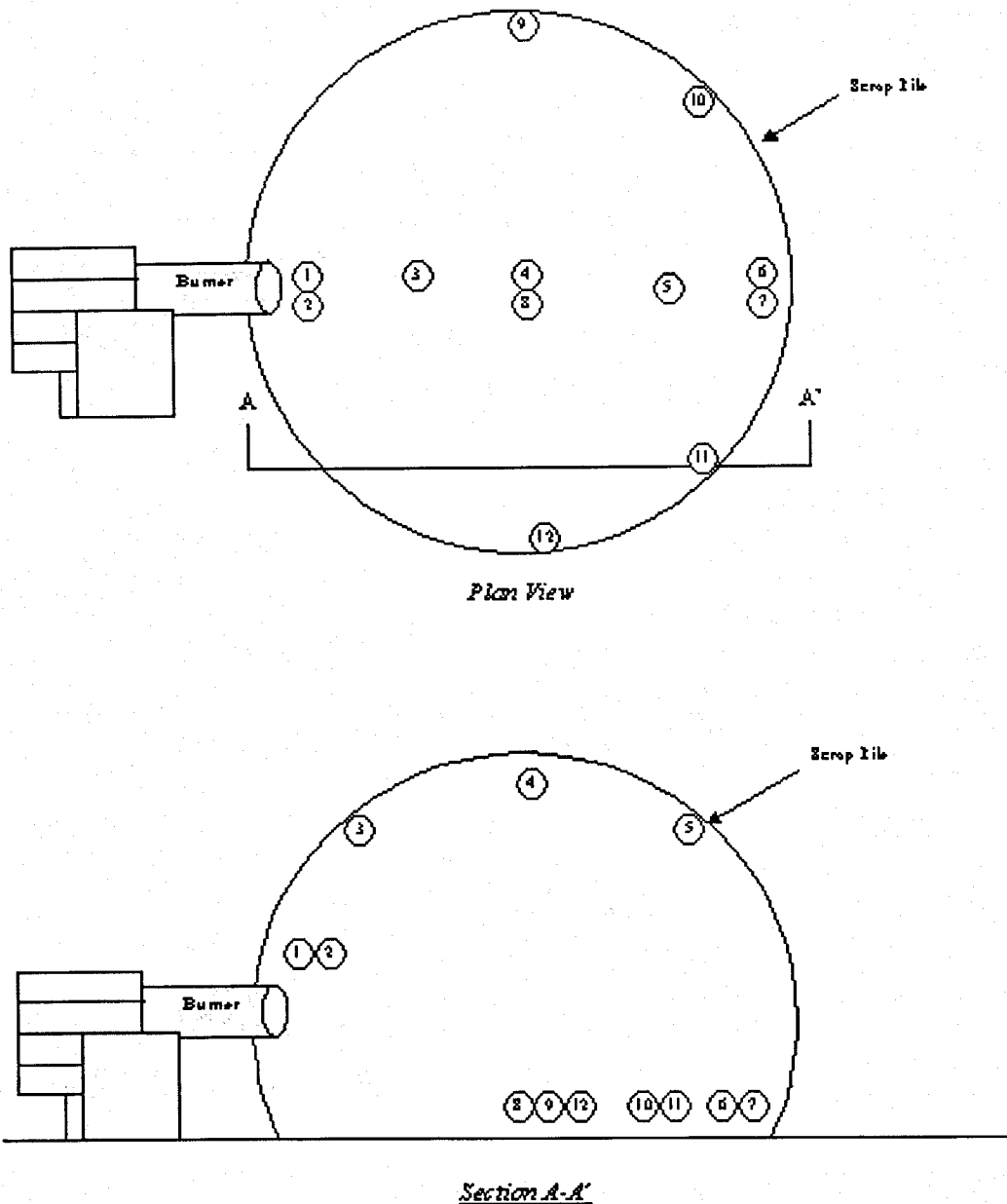


Figure 5.1-1. Thermocouple Location for Test Pile #1

of the pile was covered with approximately 85 ft² of Ametek® high temperature Siltemp™ insulating fabric. In addition, the entire pile was covered with approximately 56 ft² of ½" and approximately 450 ft² of 1" high temperature Ametek® AB100U Silmat™ and approximately 450 ft² of one-inch medium temperature BGF® mat. The blankets were secured to the pile using baling wire and ten penny nails. In addition, three lengths of chicken wire that measured approximately 28 feet in length or 84 ft² were placed across the pile with 2 in an X pattern with one across the middle of the pile. In total approximately 168 ft² of chicken wire was used draped

FINAL

over the insulation. The chicken wire was secured into the ground using 6 steel stakes. Note: During the Silmat™ installation, the Silmat™ started tearing and falling apart. Further discussion between Parsons and Ametek® revealed that the (less expensive) “unshrunk” U-type Silmat™ used in Test 1 was not durable and had little tensile strength; while the more durable Shrunk S-type Silmat™ was hardy and more appropriate for this service. Ametek® provided 5 boxes of the Shrunk S-type Silmat™ for future testing. Maintenance time was 16 man-hours to cover this pile.

Decontamination Phase. The test objective was to determine the effectiveness of the decontamination process with a test temperature of 600°F with a 6-hour heat soak time. During the heat-up phase of Pile 1, a one-inch by 15-foot gap was noted at the top of the pile caused by a shift in the thermal blanket. An attempt to mitigate the problem was made by securing one 12' long (36 ft²) and one 5' long (15 ft²) section of the high temperature Siltemp™ thermal fabric perpendicular to the gap. The Siltemp™ was secured to the chicken wire using baling wire. During the heat-up operations, the following events were observed: A large amount of steam was escaping through the aforementioned gap and various seams throughout and from under the pile. The steam was believed to be a result of water accumulated in the 5 dumpsters that contained scrap used in the pile formation. In addition, parts of the high temperature Siltemp™ turned black, and the one-inch “unshrunk” Silmat™ continued to fall apart. The BGF® mat kept its form and discolored slightly. A picture of the after-trial condition of the blankets is shown in Figure 5.1-2.

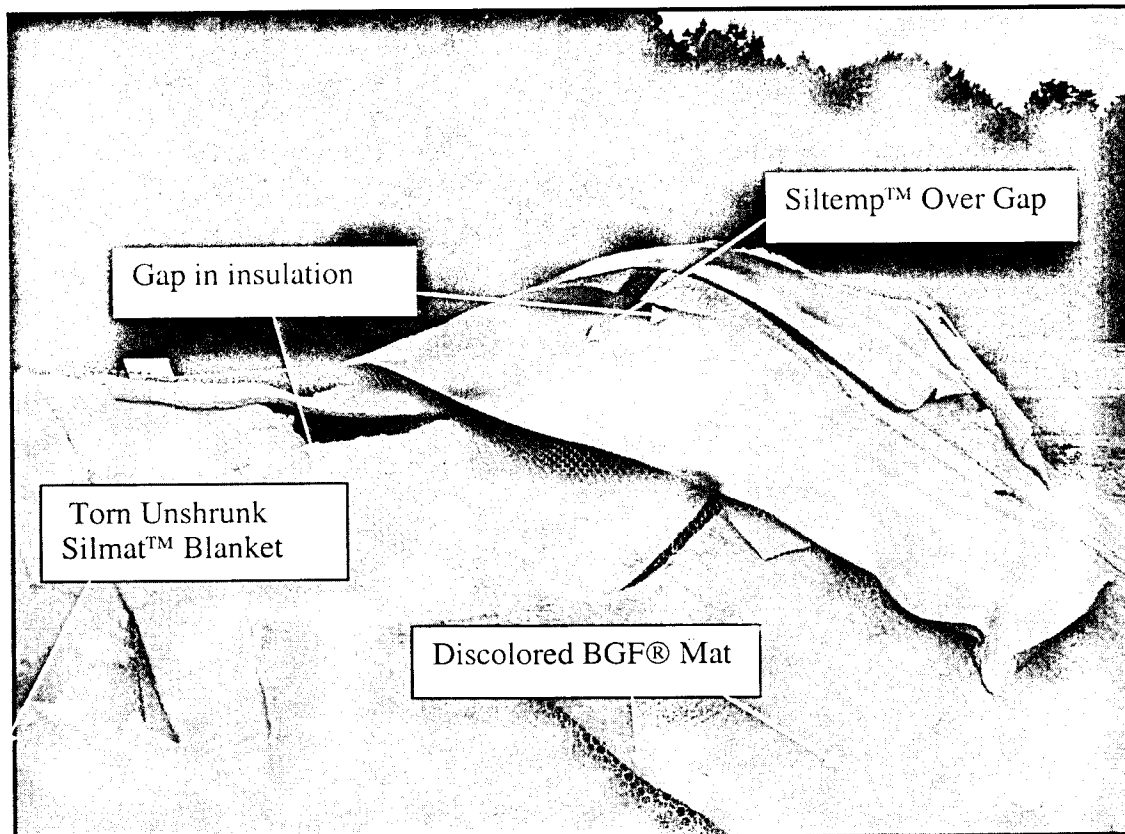


Figure 5.1-2. After Test 1 Blanket Conditions

FINAL

Burner Performance. During Test #1, it was noted that the firing rate of the burner was set in a manner that cycled it from full on to full off as the temperature reached the override temperature setpoint. This did not allow the burner to maintain the highest firing rate possible. The burner should be allowed to maintain the highest firing rate possible to reduce heat up times. A software change was downloaded into the Operator's Workstation (OW) computer, which allows the burner to maintain (control) the highest temperature possible to reduce heat up times.

Thermocouples. During Test 1, the thermocouple signals were transmitted to the operator workstation via wireless remote for recording and decision-making. During heat up phase of Test 1, the thermocouples indicated when their location had met the predetermined temperature criteria of 600°F. For this trial, all of the thermocouples had to reach a soak temperature of 600°F before the 6-hour heat soak time could start. Unfortunately, during the burner heat-up time, a loss of communications fault was received at the OWS. Inspection revealed that the generator was inoperative. Further inspection revealed that the generator auxiliary fuel pump was inoperative. Test 1 was ended and further testing delayed for a day so that the generator auxiliary fuel pump could be replaced. A checkout of maintenance revealed that once the generator was repaired the HGD system was operational.

Time and Temperature Summary. According to the Final Demonstration Plan¹⁷ (Appendix B) Table 3.6.1, the first test trial was designated as a "proof of concept" test. The test objective was to determine the effectiveness of the decontamination process with a test temperature of 600°F with a 6-hour heat soak time. The complete time and temperature data for this trial is located in Appendix B of this report. The time and temperature data for Test 1 are summarized in Table 5.1-1 and 5.1-2.

Table 5.1-1. Time and Temperature Data Summary – Test 1.

Event	Date	Start Time	Date	Stop Time	Total Time
Heat-Up	16 Aug 01	1456	16 Aug 01	1818	3 hrs 22 min
Soak Time	--	--	--	--	--
Approximate Cool Down Time	--	--	--	--	--

Table 5.1-2. Thermocouple Time to 600°F

Thermocouple Number	Date	Heat-up Start Time	Time 600°F was Reached	Actual Temperature	Elapsed Time
3	16 Aug 01	1456	1626	609.2	1 hr 30 min
4	16 Aug 01	1456	1629	602.3	1 hr 33 min
1	16 Aug 01	1456	1646	601.8	1 hr 50 min
2	16 Aug 01	1456	1653	605.5	1 hr 57 min
5	16 Aug 01	1456	1709	600.6	2 hr 13 min

FINAL

Test 1 Burner and Equipment Performance Assessment

The HGD system failed to meet its performance objectives in Test 1 due to generator failure and loss of power. In Test 1, the Unshrunk Silmat™ was fragile, and exhibited little tensile strength and was thereby difficult to handle and install. For this reason, the insulation blanket for Test 1 had tears and gaps resulting in major heat leaks. The redeeming value of Test 1 was that it was a good startup and shakedown of equipment and materials.

While the test was a failure as far as system performance and useable data, the test served the purpose to systemize and startup components and subsystems, and was an excellent operator training exercise. Test 1 also proved that one of the initial insulation products, Silmat™ Unshrunk AB100U was unworkable (no strength; could not support its own weight), and must be replaced for future tests. In this respect, Test 1 saved time and trouble for later tests, which were conducted with little or no difficulty. The test facilitated the later successes on subsequent tests, but did not produce useable results on its own merit.

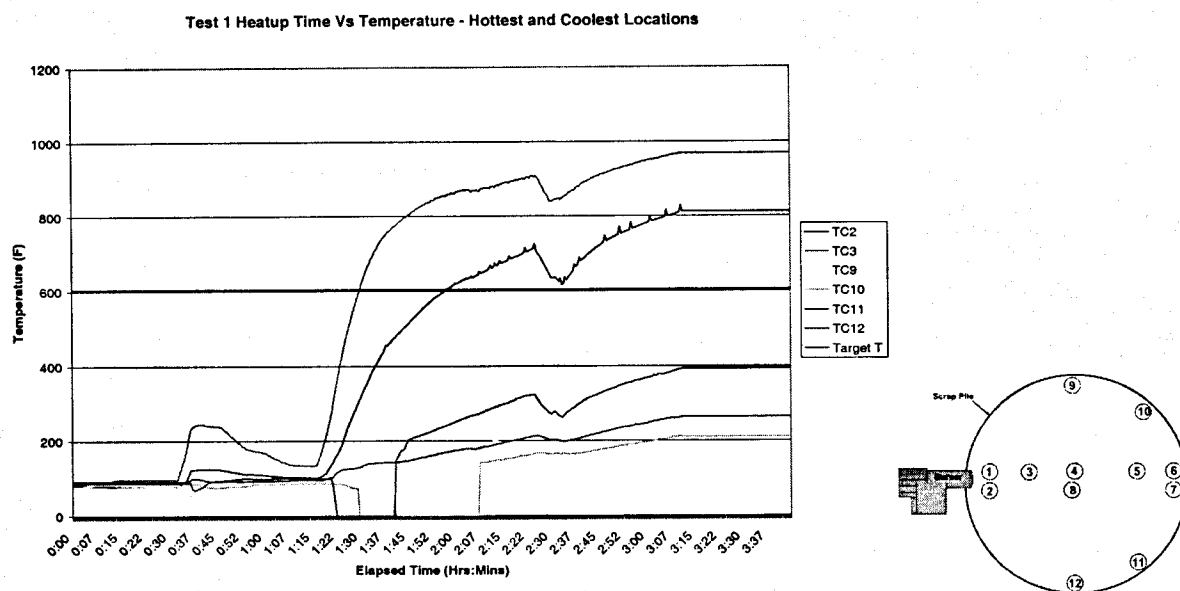


Figure 5.1-3 Test 1 Heatup Time vs. Temperature

5.1.2 Test 2 Performance Data and Assessment

Test 2 was conducted 5 September 01 with burner ignition taking place at 10:36 AM. According to the Final Demonstration Plan¹⁷ (Appendix B) heat soak performance criteria for the decontamination system was set at 550 °F for 6 hours soak period for Test 2. However, the failure during Test 1 caused the Test Director to adjust the performance criteria to that of Test 1 (600°F for 6 hours).

FINAL

Test Preparation. No additional test preparation was required beyond what was done in Test 1. Pile 1 was used again for Test 2. No modifications or repairs were required on the HGD system.

Test Execution – Insulate Pile: All of the stainless steel, the carbon steel and the galvanized steel mesh and most of the thermal blankets that were used in Test 1 were reused in Test 2 with the following exceptions: The 56 ft² of the ½ inch unshrunk Silmat™ that was draped over the propane heater shroud was no longer serviceable as a result of Test 1 was removed and replaced with 56 ft² of BGF® mat. Additionally, the 15- foot gap at the top of the pile was covered with 45 ft² of the high temperature Siltemp™ and 45 ft² with the BGF® mat going across the width of the pile. An exhaust port in the insulation was approximately six inches high and six feet long along the ground on the opposite side of the pile from the burner. Maintenance time was 7 man-hours to cover this pile.

Instrumentation-Thermocouples: Twelve thermocouple and 12 chambers were placed throughout the pile. Four additional thermocouples (#13 through #16) were placed through the I-beam at the front center of the pile as follows: #13 approximately 8 ft into the pile, #14 approximately 6 ft into the pile, #15 approximately 4 ft into the pile and #16 approximately 3 ft into the pile. At the end of each thermocouple, a two-inch square plate, 1/4-inch thick, was secured using a nut and a bolt. The thermocouple plate is shown in Figure 5.1-4. The actual locations of the thermocouples for Test 2 are shown in Figure 5.1-5.

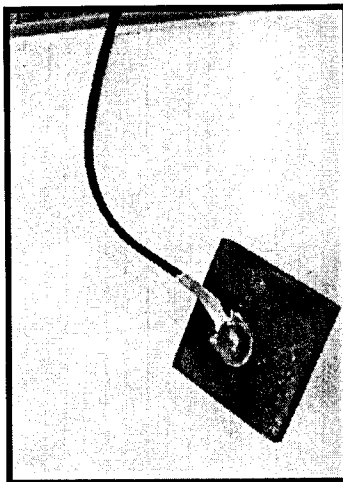


Figure 5.1-4. Thermocouple

Spiked Coupons. A total of 12 spiked coupons and 3 hand grenade fragments were strategically located on and around the scrap pile and under the thermal blankets. The actual locations and analytical results are presented in Section 5.2.

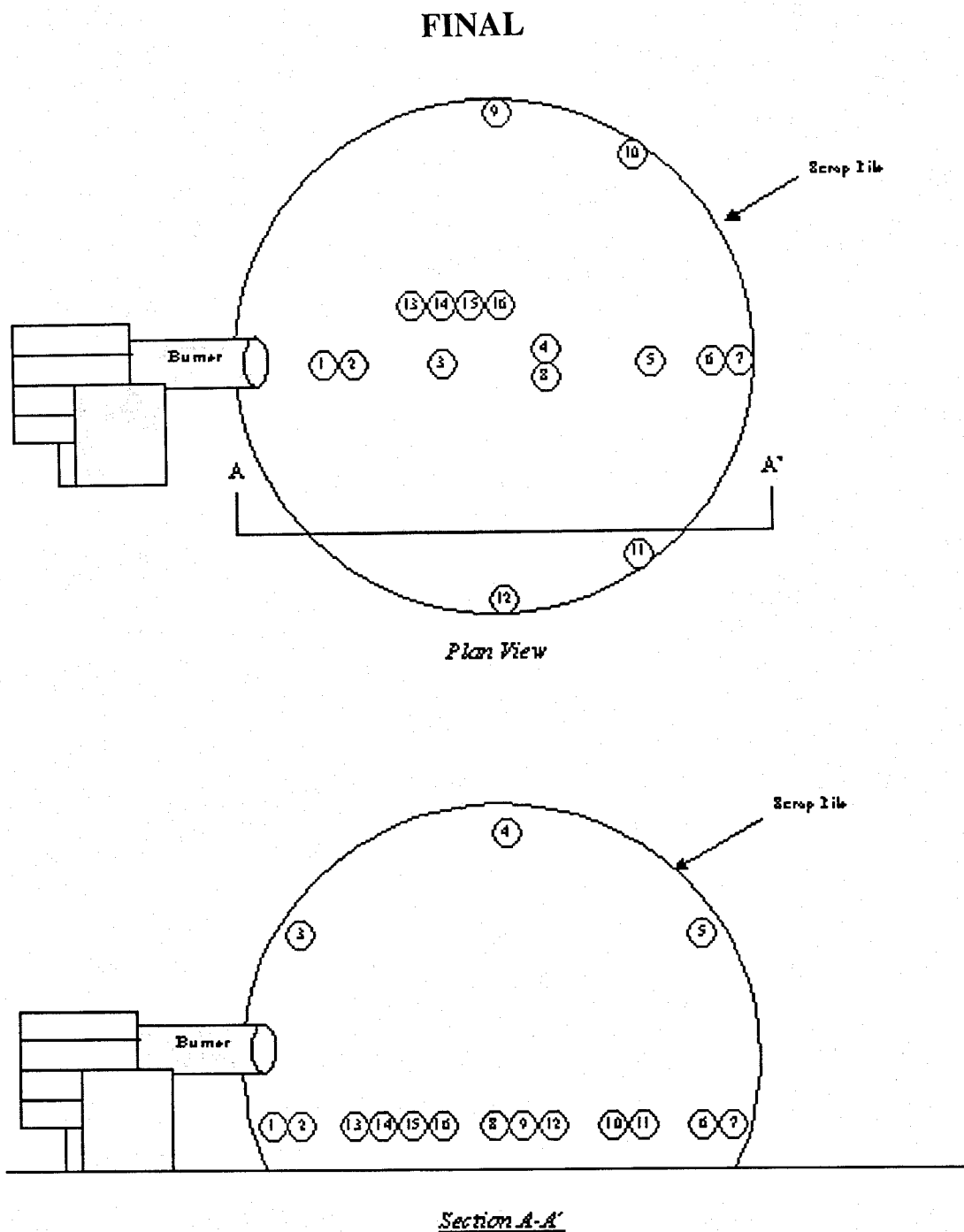


Figure 5.1-5. Thermocouple Location for Test 2

Emissions Monitoring. Emissions monitoring was conducted during this for CO, CO₂, SO₂, NO_x, TSP, PM₁₀, and PM_{2.5}, VOC, SVOC, and PAH data as well as energetic analysis. The actual instrumentation, locations, sampling and analysis methods are presented in Section 4.3.

Decontamination Phase. The test objective was to determine the effectiveness of the decontamination process with a test temperature of 600°F with a 6-hour heat soak time. During the heat-up operations, the following events were observed: The heat-up start time was at 1046

FINAL

hrs. Thermocouples #9 and #12 appeared to have difficulty in coming up to temperature. After approximately 4 hours, the burner setpoint temperature was adjusted from 1200°F to 1250°F in an attempt to get the pile (Thermocouples #9 and #12) up to temperature. After approximately another 4 hours the burner setpoint temperature was set to 1275°F. During the heat-up test, thermocouples #1, (1814 hrs) #2, (1554 hrs) #3, (1740 hrs) and #4 (1840 hrs) failed due to excessive heat. Additionally, the burner shut down three times (2111, 2233, and 2336 hrs). At 2336 hrs, the decision change the pile to soak temperature to 500°F because thermocouples #9 and #12 did not reach the required temperature of 600°F. After lowering the required temperature, a review of the time and temperature data revealed that the pile had already been at 500°F for three hours (since 2019 hrs). Since the pile had already soaked at 500°F for three hours and due to the 12-hour test limit, the decision was made at 2019 hours to start the cool down phase and shutdown the HGD system. The pile was monitored for the first 3 hours of the cool down phase. The BGF® Mat temperature blanket was discolored, but kept its form.

Test 2 Results.

Burner Performance. During heat up, which began at 1046 hours, two thermocouples could not get up to the soak temperature. At approximately 4 hours of running the setpoint was increased to 1250°F. With the thermocouples still not reaching the required temperatures the setpoint was set at 1275°F.

Thermocouples. During the heat up phase, 3 thermocouples (#2, #3, and #4) had failed due to excessive heat. Two more thermocouples could not reach the Test 1 temperature criteria of 600°F. These did not seem to be a problem with the thermocouples, but more of the inability to raise the temperature under the insulation at those spots. No other problems were reported with the thermocouples.

Time and Temperature Summary. According to the Final Demonstration Plan¹⁷ (Appendix B) in Table 3.6.1, the second test trial was designed to test the overall effectiveness of the decontamination process with a test temperature of 600°F with a 6-hour heat soak time. However, due to the inability to reach temperature in a reasonable time, a lower temperature criteria was set by the Test Director during the test. The complete time and temperature data for this trial is located in Appendix B of this report. The time and temperature data for Test 2 are summarized in Table 5.1-3 and 5.1-4.

Table 5.1-3. Time and Temperature Data Summary – Test #2

Event	Date	Start Time	Date	Stop Time	Total Time
Heat-Up	5 Sept 01	10:46	5 Sept 01	20:19	9hr 33min
Soak Time	5 Sept 01	20:19	5 Sept 01	23:19	3hr
Monitored Cool Down Time	5 Sept 01	23:19	6 Sept 01	02:19	3hr

FINAL

Table 5.1-4. Thermocouple Time to 500°F

Thermocouple Number	Date	Heat-up Start Time	Time 500°F was Reached	Actual Temperature	Elapsed Time
1	5 Sept 01	10:46	11:03	506.9	17min
2	5 Sept 01	10:46	11:01	546.3	15min
3	5 Sept 01	10:46	11:07	510.4	21min
4	5 Sept 01	10:46	11:15	503.0	29min
5	5 Sept 01	10:46	11:31	501.7	45min
6	5 Sept 01	10:46	16:06	500.2	5hr 20min
7	5 Sept 01	10:46	12:49	501.5	2hr 3min
8	5 Sept 01	10:46	15:55	501.1	5hr 9min
9	5 Sept 01	10:46	20:06	500.5	9hr 20min
10	5 Sept 01	10:46	16:47	500.2	6hr 1min
11	5 Sept 01	10:46	20:19	500.6	9hr 33min
12	5 Sept 01	10:46	17:43	500.1	6hr 57min
13	5 Sept 01	10:46	16:52	500.5	6hr 6min
14	5 Sept 01	10:46	13:50	502.6	3hr 4min
15	5 Sept 01	10:46	13:37	500.8	2hr 51min
16	5 Sept 01	10:46	13:29	502.8	2hr 43min

Burner performance data for Test 2 are presented in four graphs as follows:

- Figure 5.1-6 Test 2 System Heatup Performance – Elapsed Time vs. Temperature
- Figure 5.1-7 Test 2 Heatup Time Vs. Temperature for Hottest and Coolest Locations
- Figure 5.1-8 Test 2 Temperature Distribution versus Distance from Burner – Top of Pile
- Figure 5.1-9 Test 2 Temperature Distribution versus Distance from Burner – Bottom Perimeter of Pile

Test 2 Burner and Equipment Performance Assessment

The HGD system failed to meet it's stated performance (temperature and time of 600°F for 6 hours) goals during Test 2, when the system struggled to meet it's temperature performance goal of 600 °F in all areas of the pile. These areas left and right of the burner did not heat up in a reasonable amount of time. The temperature-time performance goals were lowered during the test by the Test Director to a temperature and time of 500°F for 3 hours soak period, for the

FINAL

convenience of the operators recognizing the late start in the day followed by 12:30 hours of operating time.

The areas of the pile left and right of burner did not heat up as desired due to the lack of hot gas circulation to those areas (with a single exhaust port in the back of the pile). Hot gas circulation in the pile was one facet of the test that could be improved on in subsequent tests.

In retrospect, Test 2 was an unqualified success when explosive spiked coupons analysis was received which indicated effective decontamination of RDX, HMX, and TNT at a lower temperature and time. This data provided input to subsequent tests that the theoretical temperature-time (600°F-6 hours) criteria established for Test 2 was too rigorous, and could be lowered substantially in later tests. The incremental approach to establish the decontamination performance criteria had taken a quantum leap, and several tests planned for later to incrementally hone in on the minimum performance criteria were no longer required.

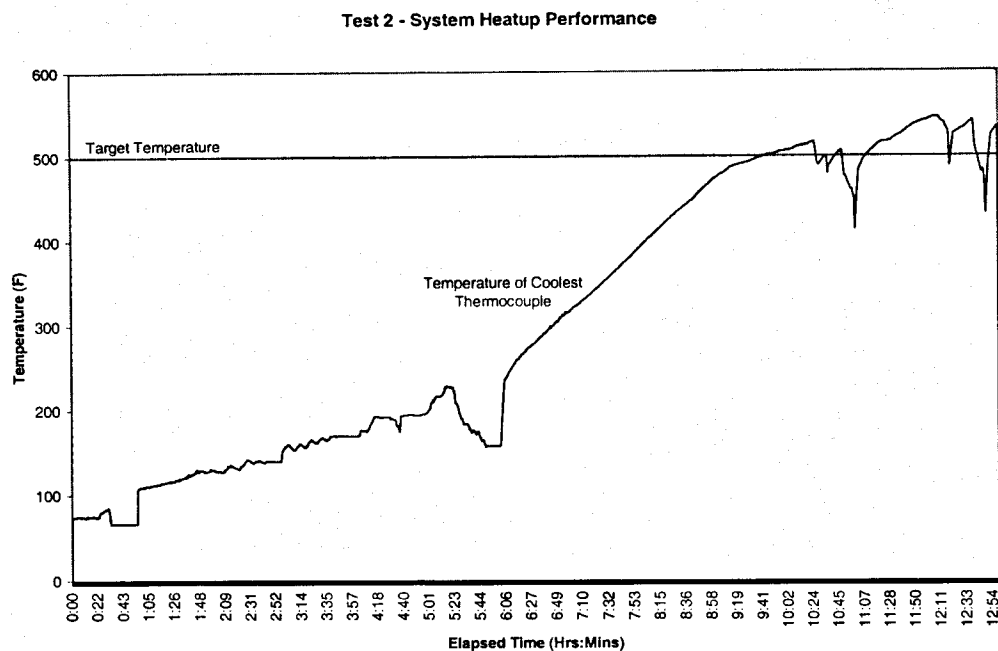


Figure 5.1-6 Test 2 System Heatup Performance – Elapsed Time vs. Temperature

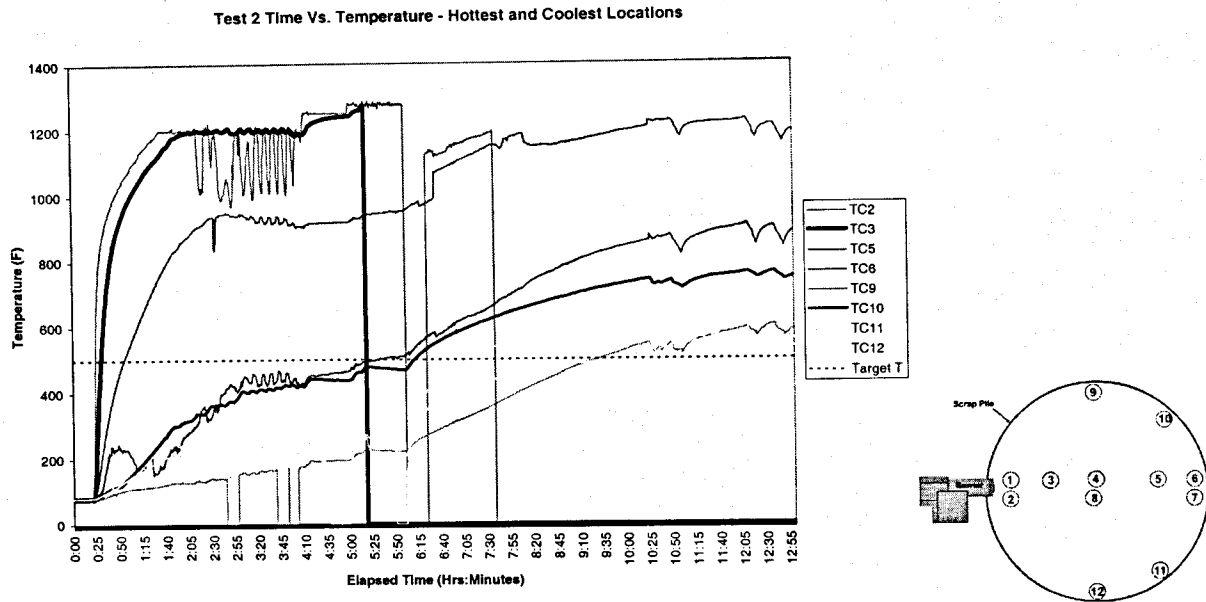


Figure 5.1-7 Test 2 Heatup Time Vs. Temperature for Hottest and Coolest Locations

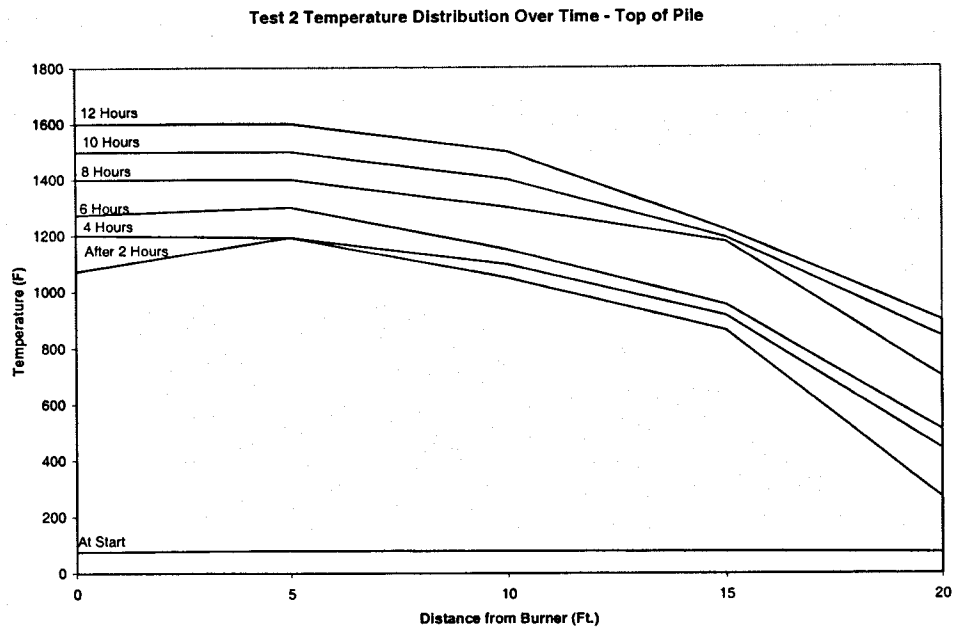


Figure 5.1-8 Temperature Distribution versus Distance from Burner – Top of Pile

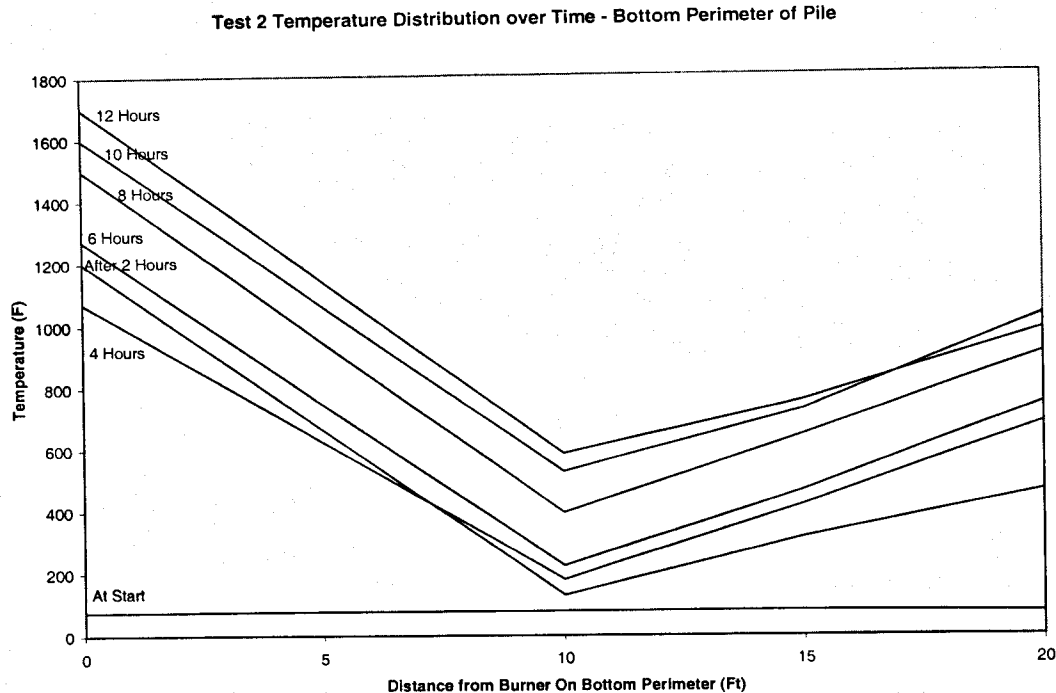


Figure 5.1-9 Temperature Distribution versus Distance from Burner – Bottom Perimeter of Pile

5.1.3 TEST 3 PERFORMANCE DATA AND ASSESSMENT

Test 3 was conducted 9 September 2001 with burner ignition taking place at 13:57. In the test matrix in the Final Demonstration Plan¹⁷ (Appendix B), the heat soak performance criteria for the burner system was originally set as 500°F for 6 hours soak period. However, in view of the successful performance in Test 2 at 500°F for 3 hours, the Test 3 performance criteria was adjusted by the Test Director to 500°F for 3 hours, to validate the results of Test 2. Pile 1 as described above was again used for Test 3. Minor maintenance to the insulation was required to prepare for Test 3.

Test Preparation. The same scrap pile (Pile1) was used. In preparation for Test 3, the HGD system was visually inspected. The inspection revealed that the thermocouples #1, #2, #3, #4, #14, and #15 were damaged. The damage consisted of worn insulation (#1), missing probes (#2, #3, and #4) and frayed insulation (#14 and #15). A small piece of Siltemp™ was wrapped around the damaged insulation to repaired thermocouple #1. Thermocouple #2, #3, #4, #14 and #15 were replaced. Maintenance time was 2.80 man-hours. No further repairs were made to the HGD system.

Test Execution – Insulate Pile. All of the stainless steel, the carbon steel and the galvanized steel mesh and most of the thermal blankets that were used in Tests 1 and 2 were reused for Test 3 with the following exceptions: Some of the insulation that was located to the front right side of the burner assembly had become solidified (hard and brittle) and was subsequently removed. A picture of the brittle insulation is shown in Figure 5.1-10 below. The pile was repaired with 114 ft² of ½" Ametek Shrunk Silmat™ (AB50S) which was placed lengthwise down the center of the

FINAL

pile and another 315 ft² of the ½" shrunk Silmat™ (AB50S) was placed width wise over the pile. To improve on hot gas circulation in the pile over Test 2, three exhaust ports in the insulation blanket were located along the ground, one each left and right of the burner centerline, and one opposite the burner. Each exhaust penetration was approximately 6 inches high by 4 feet long along the ground. A total of 15 man-hours were needed to finish the insulation.

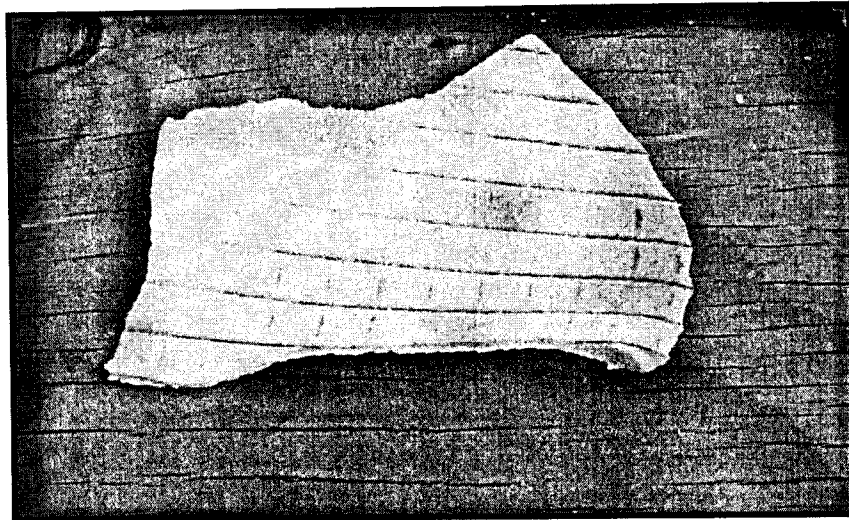


Figure 5.1-10. Brittle Insulation

Instrumentation—Thermocouples. The locations of the thermocouples for Test 3 are shown in Figure 5.1-11.

Spiked Coupon Chambers. Chambers containing one spiked coupons each were placed in the pile at thermocouple positions located 3, 4, 5, 6, and two each were placed near thermocouple locations 9, 10, 11 and 12. The chambers at location 7, 11 and 12 each contained one hand grenade fragment. The actual locations and analytical results are presented later in Section 5.2.

Emissions Monitoring. No emissions monitoring was performed for Test 3, since the pile and range scrap had previously been successfully decontaminated during Test 2. Emissions monitoring was considered unnecessary for Test 3.

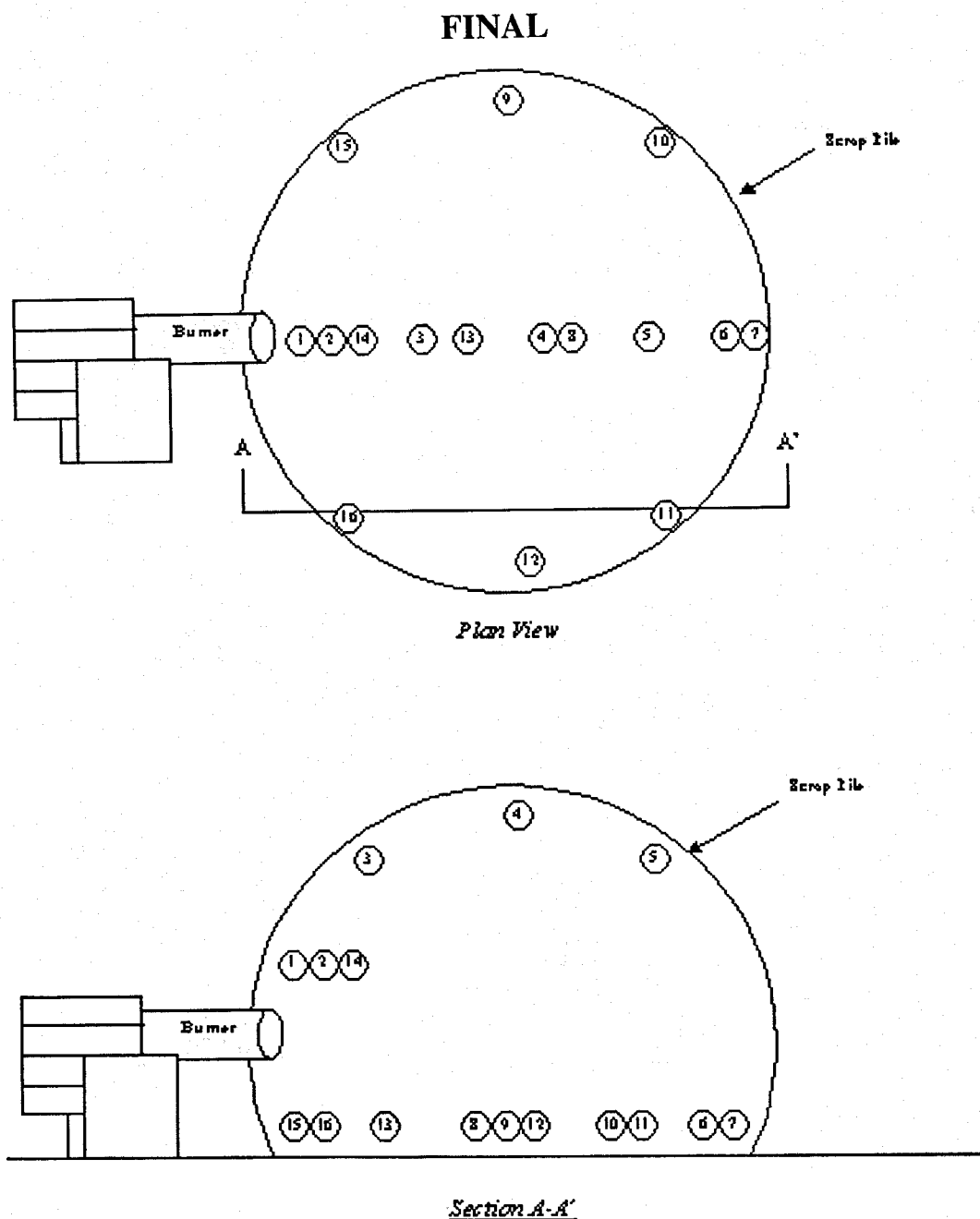


Figure 5.1-11. Thermocouple Location for Test 3

Decontamination Phase. The test objective was to verify the effectiveness of the decontamination process with a test of 500°F with a 3-hour soak time. Time and temperature data recording began at 1357 hours while the burner started at 1515 hours. The high temperature setpoint was set at 1250°F. At 1901 hours the temperature of the pile reached its required temperature and was allowed to soak for three hours before the burners were shut off and allowed ample time for cool down.

Test Results

FINAL

Burner performance. While attempting to start the burner assembly for Test 3, the error message "burner failed to ignite" appeared on the operator's workstation. Inspection revealed that the burner assembly igniter was loose. The igniter was removed and reinstalled. Another attempt was made to start the HGD system and like the previous time the same error occurred. This scenario repeated several times. Upon further investigation it was discovered that the insulation around the tip of the igniter was broken off. The igniter was repaired temporary by wrapping a small piece of electrical tape around the end of the igniter. This course of action was chosen because there was a lack of available replacement parts. After repaired the igniter was reinstalled and restarted with no more problems. Maintenance time was 1 man-hour.

Thermocouples. During Test 3, the thermocouples signals were transmitted to the operator workstation via wireless remote for recording and decision making. Thermocouple #8 lost its signal and was offline from 1727 hours to 2207 hours. This failure did not effect the start of the soak time. When the thermocouple came back online, it was reading 663.4°F well over the required temperature.

Time and Temperature Summary. The third test trial was designed to verify the effectiveness of the HGD at conditions of 500°F with a soak time of 3 hours. The complete time and temperature data for this trial is located in Appendix B of this report. The time and temperature data for Test 3 is summarized in Tables 5.1-5 and 5.1-6 below.

Table 5.1-5. Time and Temperature Data Summary – Test 3

Event	Date	Start Time	Date	Stop Time	Total Time
Heat-Up	18 Sept 01	15:15	18 Sept 01	19:01	3hr 46min
Soak Time	18 Sept 01	19:01	18 Sept 01	22:05	3hr 4min
Approximate Cool Down Time	18 Sept 01	22:05	19 Sept 01	1:05	3hr

Table 5.1-6. Thermocouple Time to 500°F

Thermocouple Number	Date	Heat-up Start Time	Time 500°F was Reached	Actual Temperature	Elapsed Time
1	18 Sept 01	15:15	15:19	506.9	4min
2	18 Sept 01	15:15	15:18	502.8	3min
3	18 Sept 01	15:15	15:30	502.3	15min
4	18 Sept 01	15:15	15:46	502.8	31min
5	18 Sept 01	15:15	16:09	501.8	54min
6	18 Sept 01	15:15	17:08	501.3	1hr 53min
7	18 Sept 01	15:15	16:39	501.2	1hr 14min
8	18 Sept 01	15:15	15:42	526.1	27min

FINAL

Table 5.1-6. Thermocouple Time to 500°F (Continued)

Thermocouple Number	Date	Heat-up Start Time	Time 500°F was Reached	Actual Temperature	Elapsed Time
9	18 Sept 01	15:15	18:36	500.0	3hr 21min
10	18 Sept 01	15:15	18:46	500.9	3hr 31min
11	18 Sept 01	15:15	17:30	500.0	2hr 15min
12	18 Sept 01	15:15	19:01	500.0	3hr 46min
13	18 Sept 01	15:15	18:45	500.3	3hr 30min
14	18 Sept 01	15:15	15:25	500.4	10min
15	18 Sept 01	15:15	16:25	500.6	1hr 10min
16	18 Sept 01	15:15	15:30	502.8	15min

Results for Test 3 are presented in four graphs as follows:

- Figure 5.1-12 Test 3 System Heatup Performance – Elapsed Time vs. Temperature
- Figure 5.1-13 Test 3 Heatup Time Vs. Temperature for Hottest and Coolest Locations
- Figure 5.1-14 Test 3 Temperature Distribution versus Distance from Burner – Top of Pile
- Figure 5.1-15 Test 3 Temperature Distribution versus Distance from Burner – Bottom Perimeter of Pile

Test 3 Burner and Equipment Performance Assessment

During Test 3, the transportable HGD system successfully decontaminated the spiked coupons in the pile in 7 hours of total operating time, including approximately 4 hours heatup time and 3 hours soak time at 500°F (see Section 5.2 for coupon results). Test 3 validated the results of Test 2 that established effective temperature-time criteria of 500°F. In doing so, Tests 2 and 3 were a quantum leap in establishing time and temperature criteria for effective decontamination, thereby eliminating the incremental approach to decreasing time and temperature that was previously planned in the test matrix in the Final Demonstration Plan¹⁷ (Appendix B). As a result, a reduced number of tests were necessary to accomplish one project objective (i.e. to establish effective decontamination criteria for temperature and time).

In addition, Test 3 accomplished another operational objective by decontaminating approximately 14.5 tons of range scrap in 7 hours, within the one 8-hour shift objective.

Test 3 proved that multiple exhaust ports were far superior to a single exhaust port in terms of hot gas circulation. Test 3 showed the importance of convection (from the hot gas circulation) as a heat transfer mechanism, over conduction and/radiation through the pile. Test data from Test 3 also showed cold spots in the outer extremes of the pile in between exhaust ports, indicating further improvements to hot gas circulation in subsequent tests was warranted.

FINAL

Test 3 System Heatup Performance

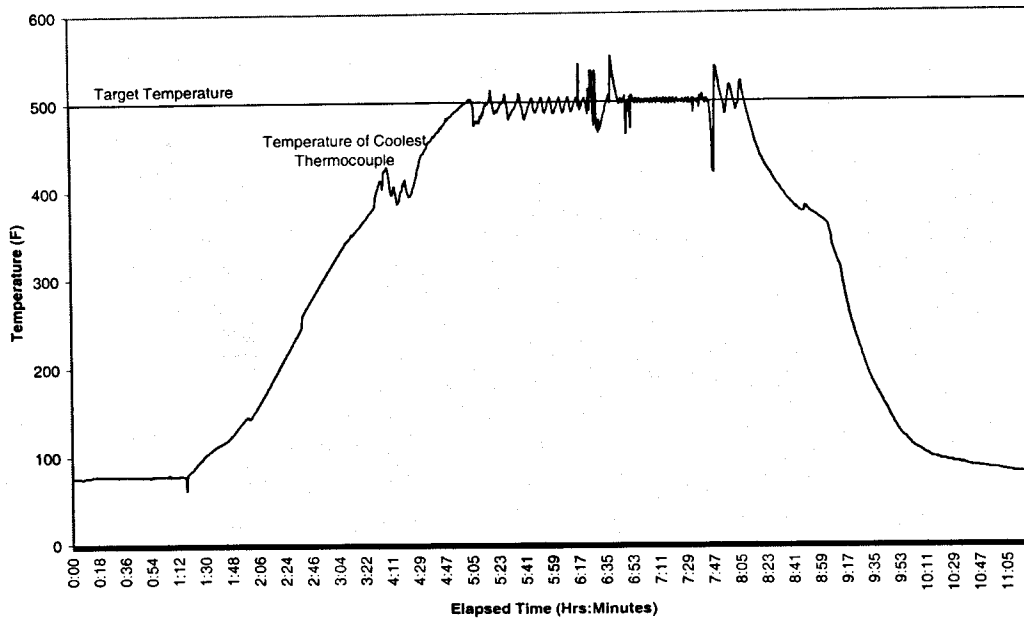


Figure 5.1-12 Test 3 System Heatup Performance – Elapsed Time vs. Temperature

Test 3 Time Vs. Temperature - Hottest and Coolest Thermocouples

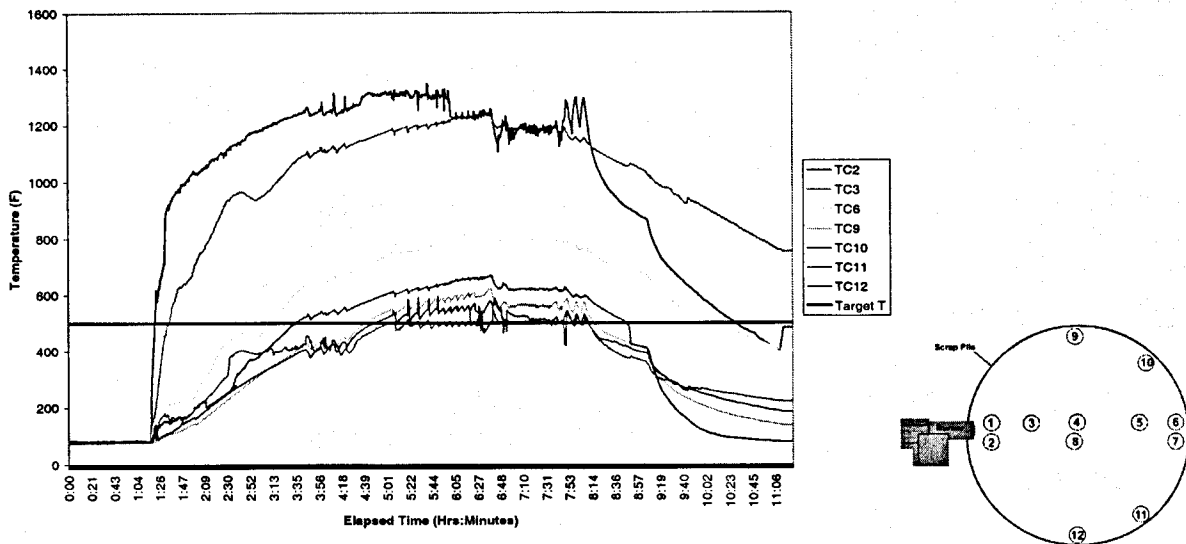


Figure 5.1-13 Test 3 Heatup Time Vs. Temperature for Hottest and Coolest Locations

FINAL

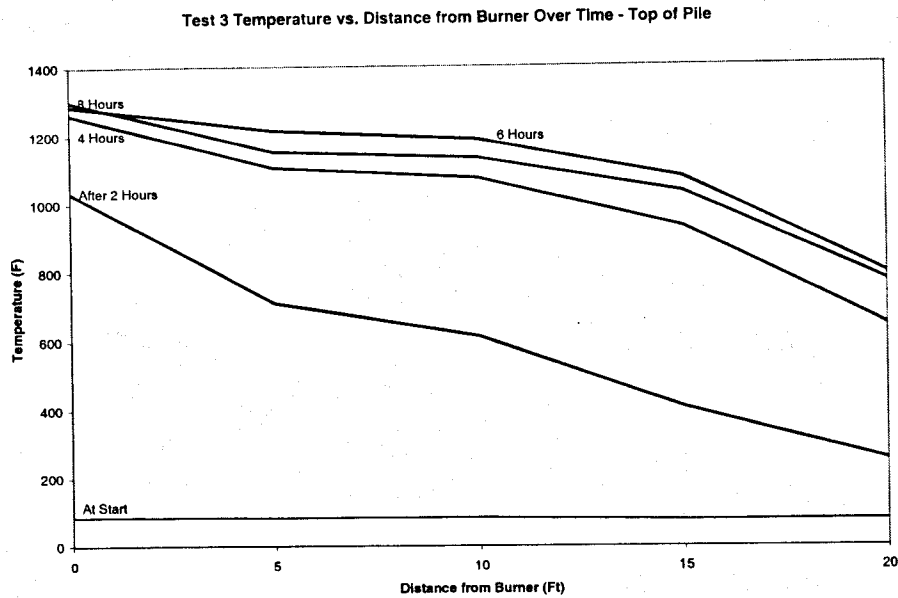


Figure 5.1-14 Test 3 Temperature Distribution versus Distance from Burner – Top of Pile

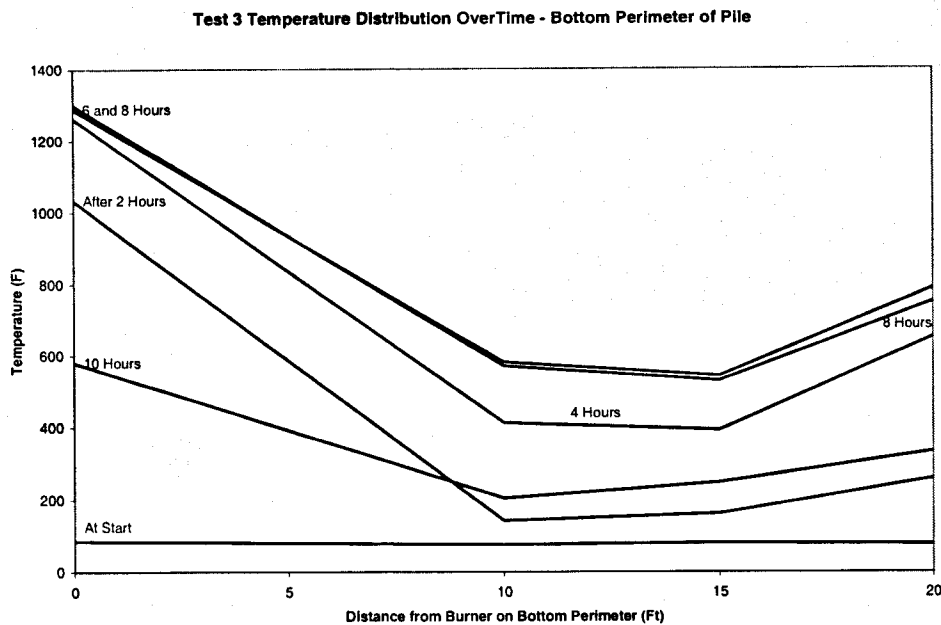


Figure 5.1-15 Test 3 Temperature Distribution versus Distance from Burner – Bottom Perimeter of Pile

5.1.4 TEST 4 PERFORMANCE DATA AND ASSESSMENT

Test 4 was conducted on 28 September 2001 and the burner ignition taking place at 09:43 AM. In an effort to reduce processing time, the heat soak performance criteria for the burner system was set at 500°F and the heat soak period reduced to 2 hours for Test 4. The heat soak

FINAL

performance criteria was lowered to 500 °F for 2 hours from 500 °F for 3 hours (previously proven effective decontamination criteria in Test 3), in order to test the lower limits of the system and establish the minimum temperature-time relationship required to decontaminate the scrap. Pile 1 was again used for Test 4, as in the previous 3 tests.

Test Preparation. During the original start up for Test 4, the burner would not ignite. In an attempt to correct the problem, the igniter was reinstalled into the burner. Several attempts were made to ignite the burner with no success. At that time, it was decided to delay Test 4 until the new igniter was received. Upon receipt of the new igniter, the damaged igniter was removed and the new one was installed. A checkout of maintenance revealed that the burner was operational with the new igniter. Maintenance time was 1.6 of a man-hour total for both days.

Test Execution – Insulate Pile. The BGF® mat around the burner shroud was removed and was replaced with 56 ft² of the ½" shrunk Silmat™. Two more pieces of the BGF® mat from the top center of the pile and from the front right side of the pile were removed. The existing blankets on the pile were rearranged to compensate for the removed BGF® mat. The configuration of the hot gas circulation was again revised by using a continuous one inch high slit along the ground for the entire back end of the pile (180° of the pile).

Maintenance time was 1.5 man-hours.

Instrumentation-Thermocouples. From the previous pile arrangement thermocouples #8 and #13 were removed from the center of the pile and were placed at the outside edge of the pile. No other changes were made. The actual locations of the thermocouples for Test 4 are shown in Figure 5.1-16.

Spiked Coupon Chambers. Twelve chambers containing one spiked coupons each were placed in the pile at thermocouple positions 3, 4, 5, 6, 9A, 9B, 10A, 10B, 11A, 11B, 12A, and 12B. Additionally, the chambers at location at thermocouple positions 9A, 9B, and 12A contained one spiked coupon one hand grenade fragment. The actual locations and analytical results are presented in Section 5.2.

Emission Monitoring. No emission data was needed or collected for this pile.

Decontamination Phase. The test objective was to optimize of the HGD process with a test temperate of 500°F with a 2-hour soak time. During the heat up of pile #4, a 12 ft² of Siltemp™ was used to cover a small opening that was noted at the top backside of the pile, which was caused be a shift in the thermal blankets. Also, the thermocouples on both outside edges of the pile had difficulty in reaching temperature. To attempt to redirect the heat better 90 ft² of Silmat™ were placed on the back and outside edges of the thermal blanket in an effort to redirect the heat and allow the thermocouples on the back and outer edges of the pile to reach temperature. Even with this change, thermocouples 10 and 12 were not showing any signs of reaching temperature and were disabled. In addition thermocouple # 15 was loosing temperature. Note: Thermocouples #1 through #12 were interlaced with the burner controls. Thermocouples #13 through # 16 were not interlaced with the burners controls per Parsons request.

Burner Performance. The heat-up phase of Test 4 started at 1008 hours. The burner assembly setpoint was set to 1700°F. The pile reached an overall temperature of 500°F at 1405 hours. The pile was allowed to soak at this temperature for 2 hours. No other problems or observations were noted.

FINAL

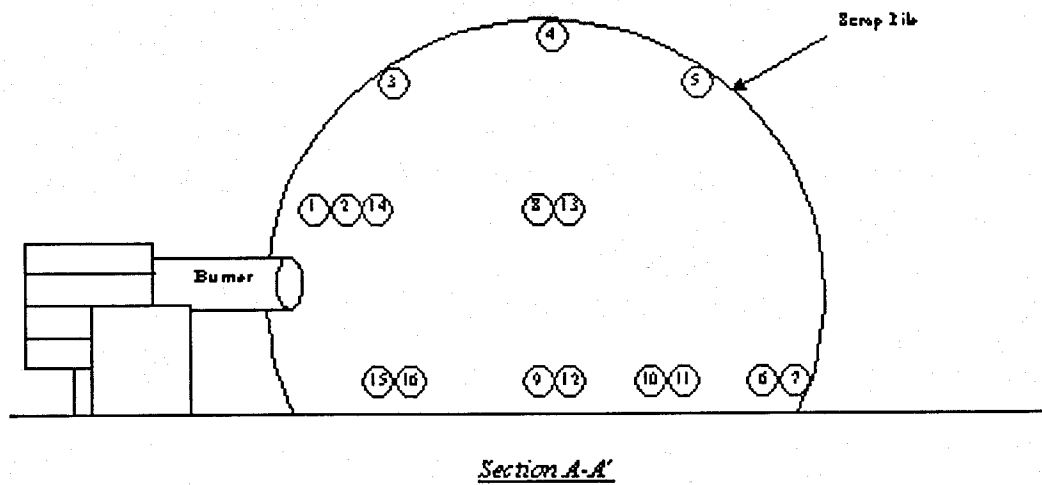
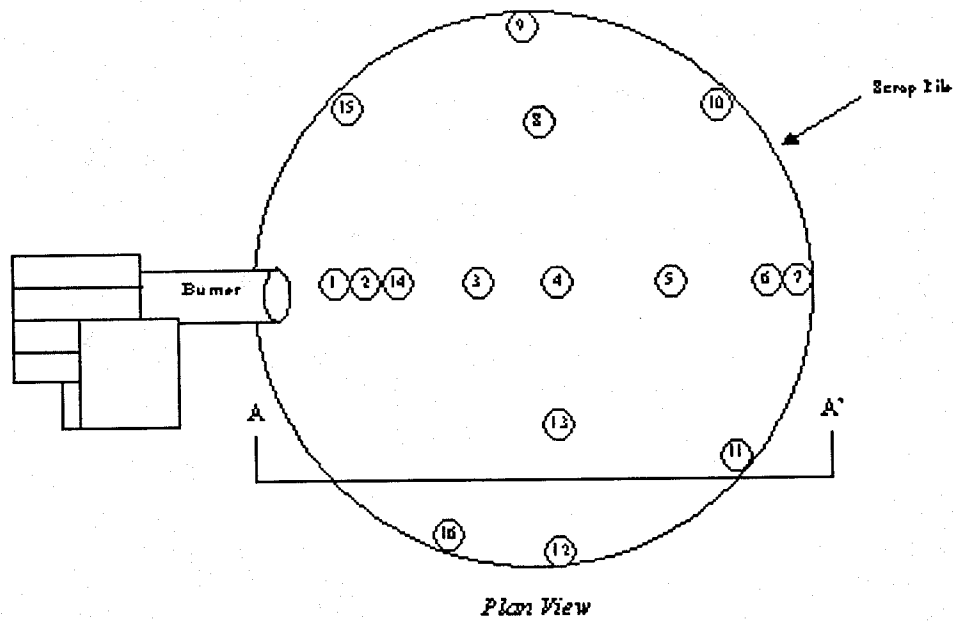


Figure 5.1-16. Thermocouple Location of Test Pile #4

FINAL

Thermocouples. During Test 4 the thermocouple signals were transmitted to the operator workstation via wireless remote for recording and decision-making. The thermocouples indicated when their location (with the exceptions of #10, #12 & #15) had met the predetermined temperature of 500°F. During the heat up two thermocouples (10 and 12) were disabled because they were not going to reach the required temperature. Thermocouple 15 also never reached temperature.

Time and Temperature Summary. The fourth test trial was designed to optimize the effectiveness of the decontamination process with a test temperature of 500°F with a 2-hour heat soak time. The complete time and temperature data for this trial is located in Appendix B of this report. The time and temperature data for Test 4 are summarized in Table 5.1-7 and 5.1-8.

Spiked Coupon Results. This trial failed to remove the HMX from spiked coupons 9A and 9B. Thus, it is believed the 2-hour soak time at 500°F was not a sufficient amount of time to decontaminate the scrap. It was observed that two layers of thermal blankets helped heat-up the pile quicker.

Table 5.1-7. Time and Temperature Data Summary – Test 4

Event	Date	Start Time	Date	Stop Time	Total Time
Heat-Up	28 Sept 01	10:08	28 Sept 01	14:05	3hr 57min
Soak Time	28 Sept 01	14:05	28 Sept 01	16:05	2hr
Approximate Cool Down Time	28 Sept 01	16:05	28 Sept 01	19:05	3hr

Table 5.1-8. Thermocouple Time to 500°F

Thermocouple Number	Date	Heat-up Start Time	Time 500°F was Reached	Actual Temperature	Elapsed Time
1	28 Sept 01	10:08	10:11	520.6	3min
2	28 Sept 01	10:08	10:11	535.0	3min
3	28 Sept 01	10:08	10:21	509.2	13min
4	28 Sept 01	10:08	10:33	508.7	25min
5	28 Sept 01	10:08	10:56	500.0	48min
6	28 Sept 01	10:08	11:40	512.6	1hr 32min
7	28 Sept 01	10:08	12:04	501.4	1hr 56min
8	28 Sept 01	10:08	10:18	506.0	10min
9	28 Sept 01	10:08	13:49	565.7	3hr 41min
10	28 Sept 01	10:08	--	--	--
11	28 Sept 01	10:08	14:05	500.4	3hr 57min

FINAL

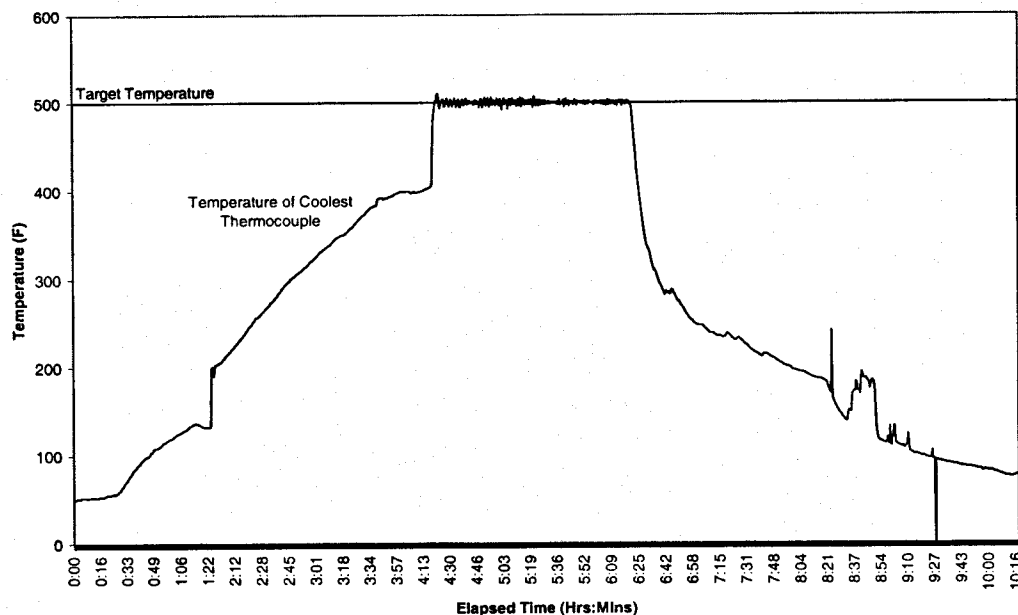
Table 5.1-8. Thermocouple Time to 500°F (Continued)

Thermocouple Number	Date	Heat-up Start Time	Time 500°F was Reached	Actual Temperature	Elapsed Time
12	28 Sept 01	10:08	--	--	--
13	28 Sept 01	10:08	10:32	501.4	24min
15	28 Sept 01	10:08	--	--	--
14	28 Sept 01	10:08	10:17	505.9	9min
16	28 Sept 01	10:08	10:38	502.1	30min

The time-temperature performance data collected by the Data Acquisition System is presented in Appendix B. This data has been tabulated and summarized in graphical form with results for Test 4 presented in four graphs as follows:

- Figure 5.1-17 Test 4 System Heatup Performance – Elapsed Time vs. Temperature
- Figure 5.1-18 Test 4 Heatup Time Vs. Temperature for Hottest and Coolest Locations
- Figure 5.1-19 Test 4 Temperature Distribution versus Distance from Burner – Top of Pile
- Figure 5.1-20 Test 4 Temperature Distribution versus Distance from Burner – Bottom Perimeter of Pile

Test 4 - System Heatup Performance



FINAL

Figure 5.1-17 Test 4 System Heatup Performance – Elapsed Time vs. Temperature

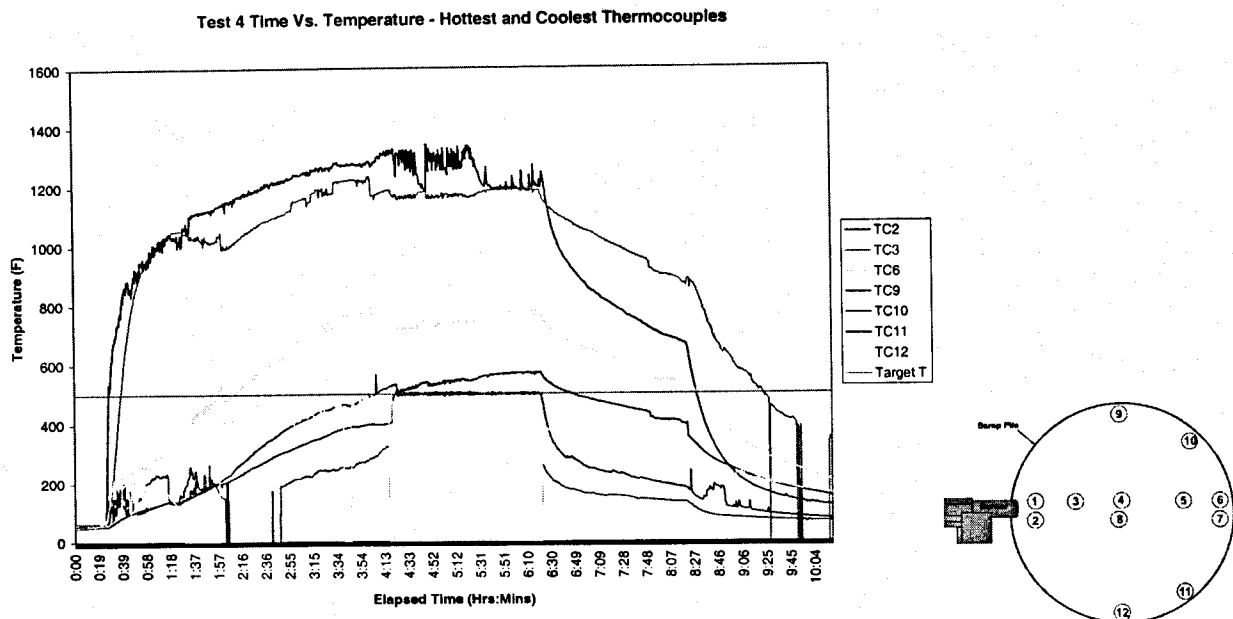


Figure 5.1-18 Test 4 Heatup Time Vs. Temperature for Hottest and Coolest Locations

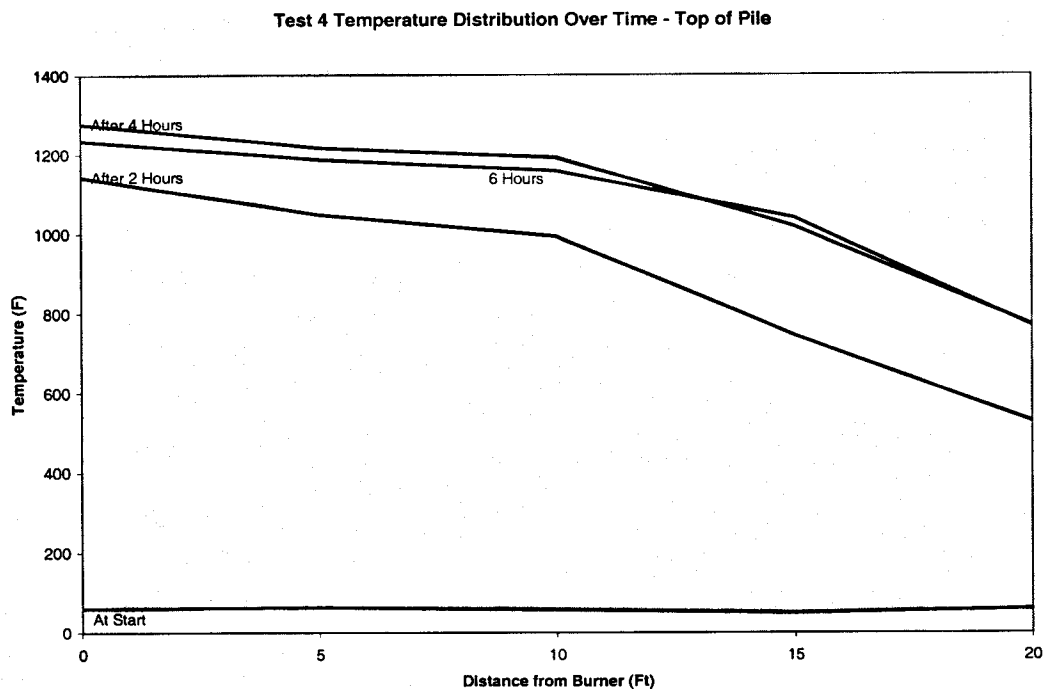


Figure 5.1-19 Test 4 Temperature Distribution versus Distance from Burner – Top of Pile

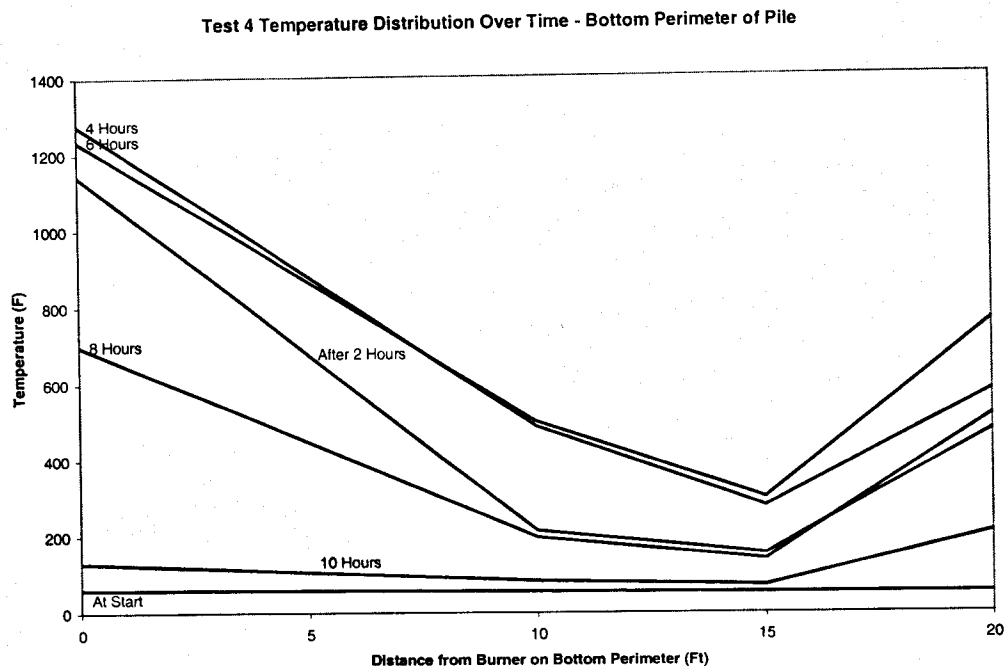


Figure 5.1-20 Test 4 Temperature Distribution versus Distance from Burner – Bottom Perimeter of Pile

Test 4 Burner and Equipment Performance Assessment

During Test 4, the transportable HGD system successfully decontaminated most of the spiked coupons in the pile in 6 hours of total operating time, including approximately 4 hours heatup time and 2 hours soak time at 500°F (see Section 5.2 for coupon results). However, a failure to decontaminate one spiked coupon with HMX led to the conclusion that 2 hours was insufficient heat soak time for effective decontamination. Test 4 established a lower limit of heat soak time for 500°F to be 3 hours soak time for effective decontamination.

Test 4 proved that two layers of insulation will greatly reduce processing time (heatup in 4 hours). Also, the continuous exhaust port configuration lent itself to more uniform hot gas circulation and fewer cold spots (i.e. quicker and better performance).

5.1.5 TEST 5 PERFORMANCE DATA AND ASSESSMENT

Test 5 was conducted on 4 October 2001 with burner ignition taking place at 10:02 AM. To further reduce the overall processing time, the heat soak criteria for the burner system was set at 600 °F for 2 hours soak period for Test 5. The test was conducted on Pile 1, as with previous Tests 1 through 4.

Test Preparation. No actual test preparation was required. The same scrap pile (Pile 1) was used as in prior tests. No modifications or repairs were required on the HGD system.

Test Execution – Insulate Pile. No insulation was installed or removed.

FINAL

Instrumentation-Thermocouples. For Test 5, thermocouples #10 and #14 were switched on the burner control panel. Thermocouples #12 and #15 had their positions switched. The last move had thermocouple #16 moved to position #9. Upon arranging thermocouple #16 to its new position, it was noted that the probe was missing. The thermocouple was replaced. This procedure took 2.0 man-hours. The actual locations of the thermocouples for Test 5 are shown in Figure 5.1-21.

Spiked Coupon Chambers. Chambers containing one spiked coupons each were placed in the pile at position 5, 6, 7, and 8 while two coupons were placed at locations 9, 10, 11, and 12. The two chambers located at 9 and one chamber location at 10 each contained one hand grenade fragment. The actual locations and analytical results are presented in Section 5.2.

Emissions Monitoring. Because the range scrap in the pile (Pile 1) had been previously decontaminated during Tests 1 through 4, No emissions monitoring was needed or performed for Test 5.

Decontamination Phase. The test objective was to determine the effectiveness of the decontamination process with a test temperature of 600°F and a 2-hour soak time. The burner was started at 1013 hours. At 1632 hours the two-hour soak time began. After two-hour of soak time and appropriate cool down time the coupons were removed from the pile and taken to CRREL for explosive analysis.

Test Results.

Burner Performance. During the cool down phase, a communications failure appeared on the operator's workstation screen. The fault reset itself and started to purge. This had no effect that would have been detrimental to the trial so no action was taken. No other problems were noted.

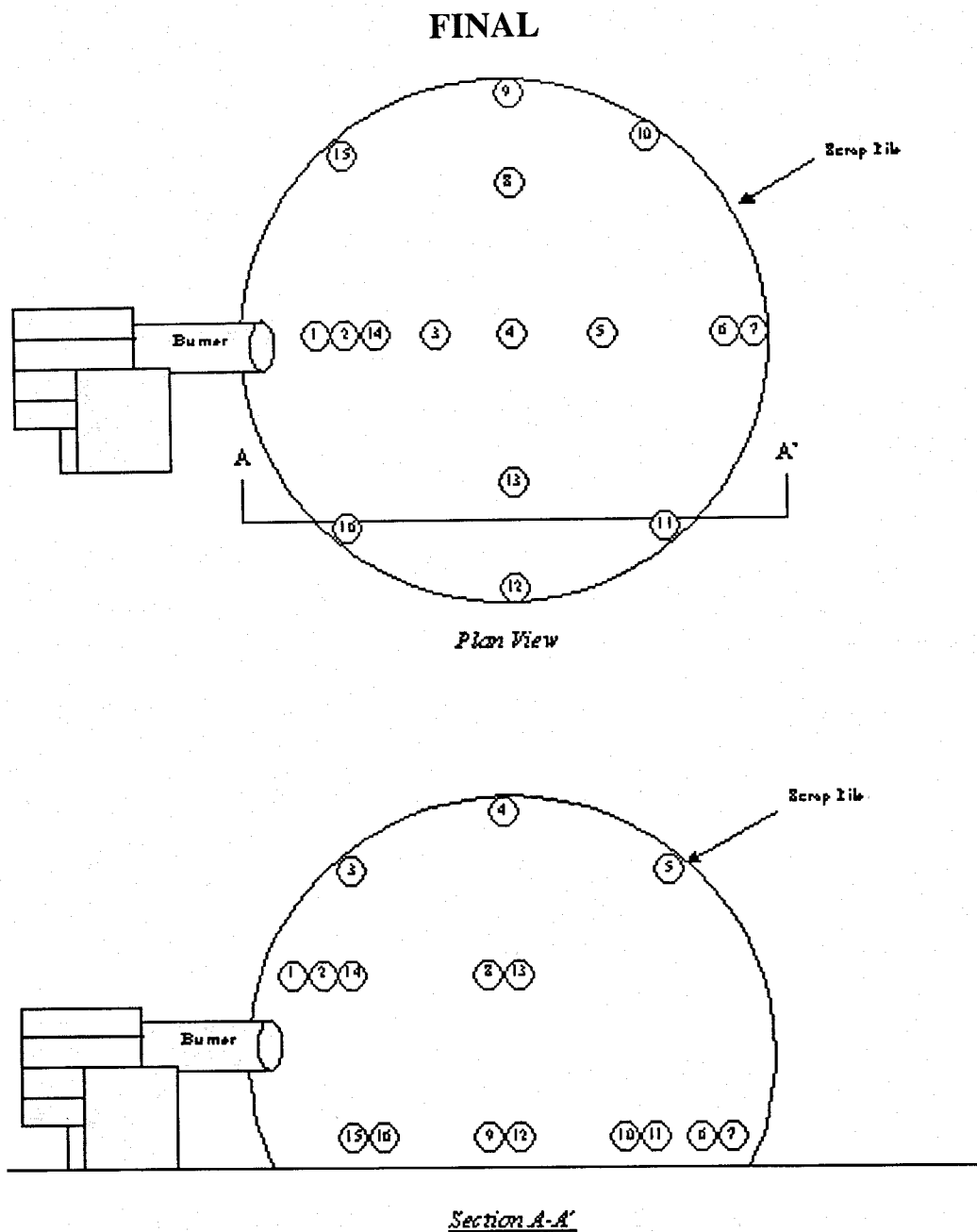


Figure 5.1-21. Thermocouple Locations for Test #5

Thermocouples. During Test 5, thermocouple #3 was noted as failed on the operator's workstation screen almost immediately after the burner assembly was ignited. Thermocouple #3 immediately reset itself and appeared as enabled on the operator's workstation screen. During the cool down of the pile, thermocouple #3 again appeared as failed of the operator's workstation screen. No action was deemed necessary at this time. All of the thermocouples are inspected prior to each new trial.

FINAL

Time and Temperature Summary. This trial was designed to test the effectiveness of the decontamination process with a test temperature of 600°F with a 2-hour heat soak time. The complete time and temperature data for this trial is located in Appendix B of this report. The time and temperature data for Test 5 are summarized in Table 5.1-9 and 5.1-10.

Table 5.1-9. Time and Temperature Data Summary – Test #5

Event	Date	Start Time	Date	Stop Time	Total Time
Heat-Up	4 Oct 01	10:13	4 Oct 01	16:32	6hr 19 min
Soak Time	4 Oct 01	16:32	4 Oct 01	18:32	2hr
Approximate Cool Down Time	4 Oct 01	18:32	4 Oct 01	21:32	3hr

Table 5.1-10. Thermocouple Time to 600 °F

Thermocouple Number	Date	Heat-up Start Time	Time 600°F was Reached	Actual Temperature	Elapsed Time
1	4 Oct 01	10:13	10:20	606.0	7min
2	4 Oct 01	10:13	10:17	631.5	4min
3	4 Oct 01	10:13	10:37	610.5	24min
4	4 Oct 01	10:13	10:42	605.4	29min
5	4 Oct 01	10:13	11:20	602.4	1hr 7min
6	4 Oct 01	10:13	12:07	601.1	1hr 54min
7	4 Oct 01	10:13	14:16	601.4	4hr 3min
8	4 Oct 01	10:13	13:48	600.5	3 hr 35min
9	4 Oct 01	10:13	14:19	600.4	4hr 6min
10	4 Oct 01	10:13	15:06	601.0	4hr 53min
11	4 Oct 01	10:13	16:32	600.4	6hr 19min
12	4 Oct 01	10:13	14:07	600.3	3hr 54min
13	4 Oct 01	10:13	10:51	600.2	38min
14	4 Oct 01	10:13	14:35	600.0	4 hr 22min
15	4 Oct 01	10:13	13:38	600.9	3hr 25min
16	4 Oct 01	10:13	15:37	602.1	5hr 24min

FINAL

Results for Test 5 are presented in four graphs as follows:

- Figure 5.1-22 Test 5 System Heatup Performance – Elapsed Time vs. Temperature
- Figure 5.1-23 Test 5 Heatup Time Vs. Temperature for Hottest and Coolest Locations
- Figure 5.1-24 Test 5 Temperature Distribution versus Distance from Burner – Top of Pile
- Figure 5.1-25 Test 5 Temperature Distribution versus Distance from Burner – Bottom Perimeter of Pile

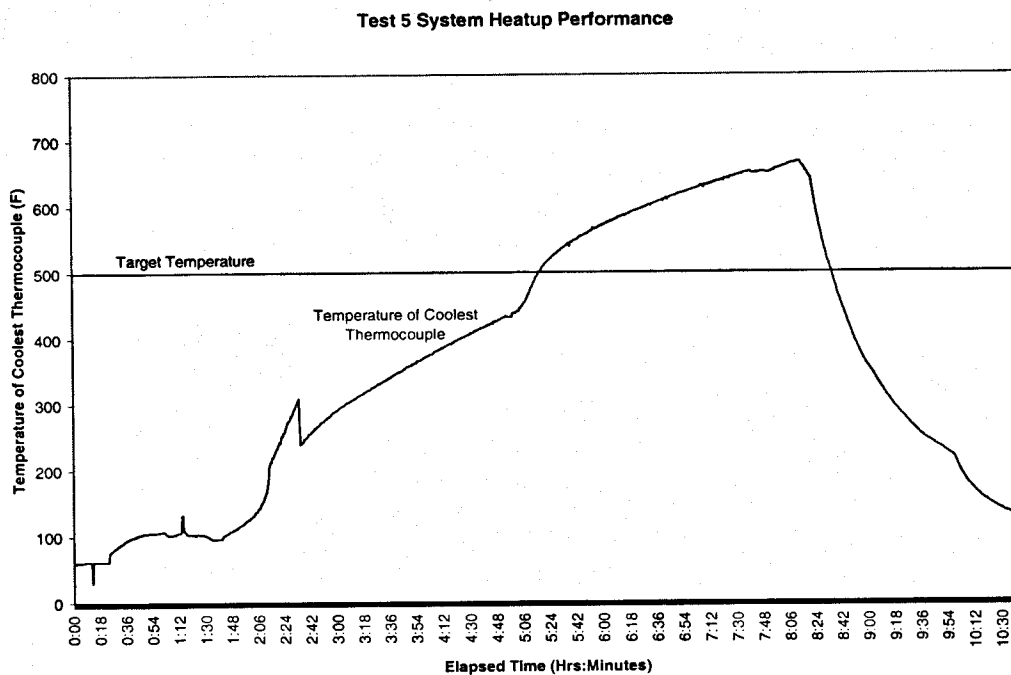


Figure 5.1-22 Test 5 System Heatup Performance – Elapsed Time vs. Temperature

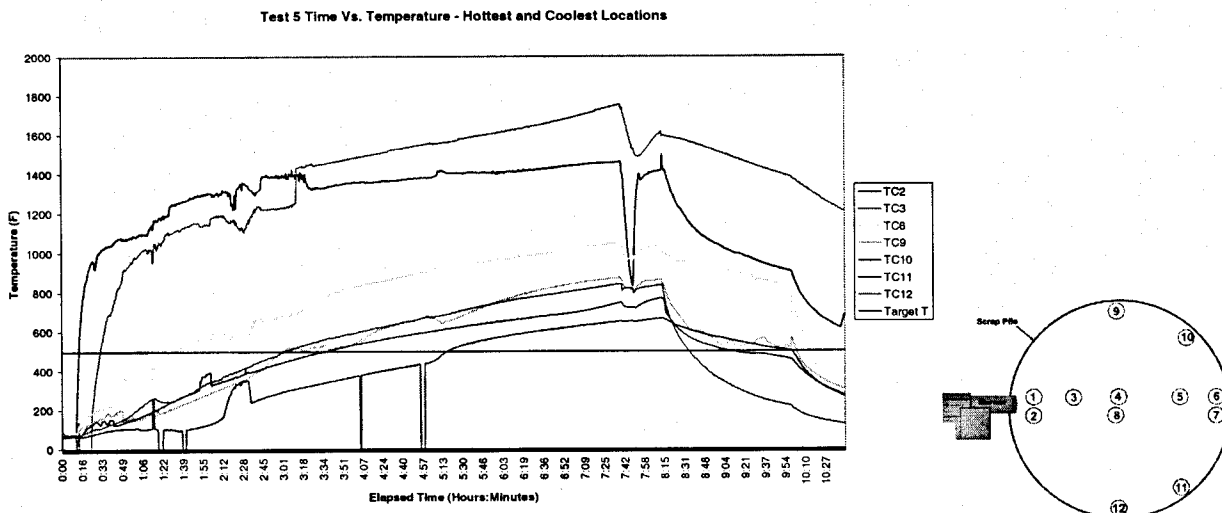


Figure 5.1-23 Test 5 Heatup Time Vs. Temperature for Hottest and Coolest Locations

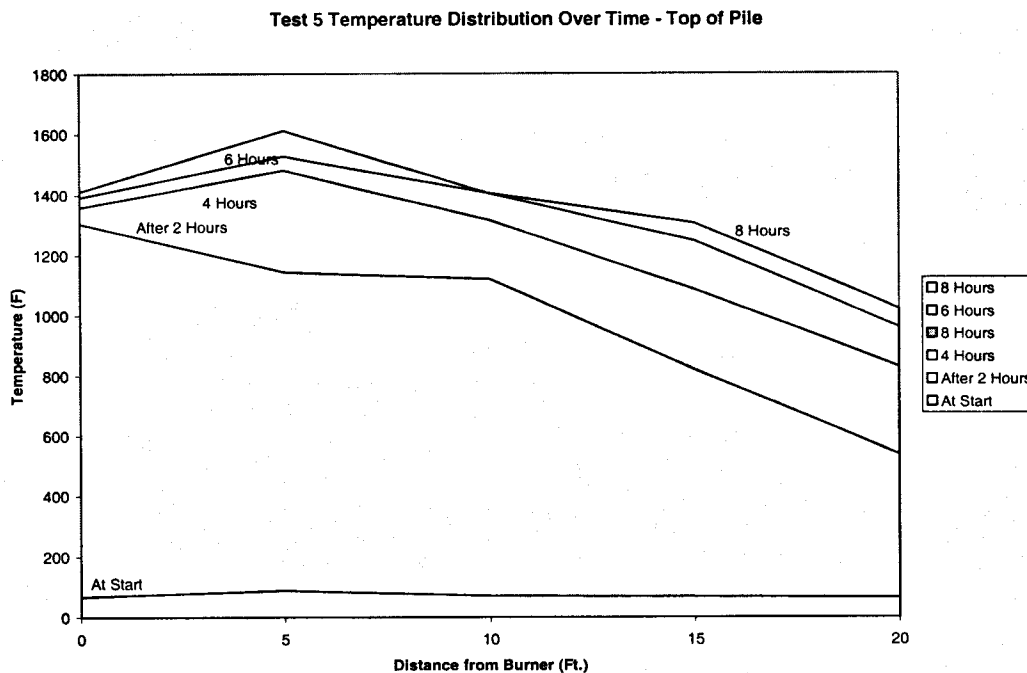


Figure 5.1-24 Test 5 Temperature Distribution versus Distance from Burner – Top of Pile

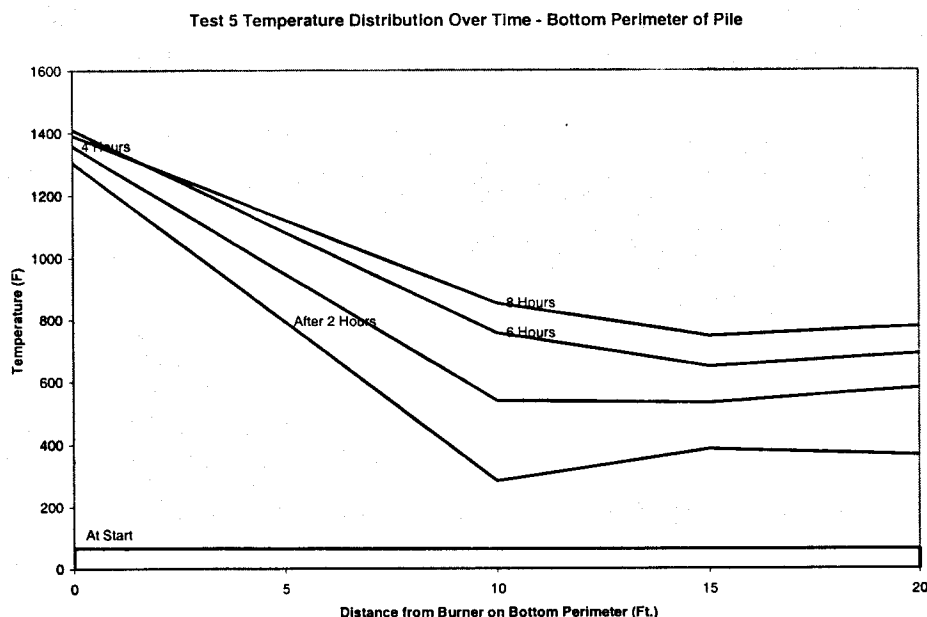


Figure 5.1-25 Test 5 Temperature Distribution versus Distance from Burner – Bottom Perimeter of Pile

Test 5 Burner and Equipment Performance Assessment

During Test 5, the transportable HGD system successfully decontaminated the spiked coupons in the pile in 8 hours of total operating time, including approximately 6 hours heatup time and 2 hours soak time at 600°F (see Section 5.2 for coupon results). The Test 5 total operating time of 8 hours at 600°F soak temperature is not as fast as experienced during Tests 2 and 3 at 500°F for 3 hours soak time (7 hours total operating time). As a result, the optimum temperature-time criteria for effective decontamination was established to be 500°F for 3 hour soak period.

5.1.6 TEST 6 PERFORMANCE DATA AND ASSESSMENT

Test 6 was conducted on 16 October 2001 with burner ignition taking place at 09:40 AM. The heat soak criteria for the burner system was set at 500 °F for 3 hours soak period (the optimum temperature-time criteria set in prior tests). A new pile of range scrap, Pile 2, was used for Test 6. Pile 2 contained munitions fragments and was 13 ft. 7 inches wide by 23 feet 7 inches long by 6 feet high, weighing approximately 20 tons. With the smaller munitions fragments than Pile 1, Pile 2 was more dense (more weight per unit volume) than Pile 1.

Test Preparation. No actual test preparation was required. The new scrap pile was used. This pile was smaller in size but consisted of much denser materials. The pile for the first 5 tests had more armor tile boxes in it, whereas this pile had more projectiles in it. No modifications or repairs were required on the HGD system.

Instrumentation-Thermocouples. An inspection of the thermocouples revealed that the leads for thermocouples #3 and #4 were worn and frayed and were replaced. Additionally,

thermocouples #16 was switched with #4, #15 was switched with #5 and #9 was switched with #8. Maintenance time was 1.0 man-hour. The actual locations of the thermocouples for Test 6 are shown in Figure 5.1-26.

Spiked Coupon Chambers. Chambers containing one spiked coupons each were placed in the pile at position 3, 4, 6, 7, and two each at thermocouple positions 9, 10, 11, and 12. One spiked coupon at 9 and both at location 12 also contained hand grenade fragments. The actual locations and analytical results are presented in Section 5.2.

Emissions Monitoring. Emissions monitoring was conducted during this for CO, CO₂, SO₂, NO_x, TSP, PM₁₀, and PM_{2.5}, VOC, SVOC, and PAH data as well as energetic analysis. The actual instrumentation, locations, sampling and analysis methods are presented in the Section 4.3.

Test Execution – Insulate Pile. During the set-up for Test 6, the following thermal blankets were used to cover the pile. Approximately 200 ft² of Siltemp™ of was used to cover the front half of the pile including the burner shroud. Approximately 254 ft² of used ½" Ametek Shrunk Silmat™ (AB50S) was reused and placed over top of the Siltemp™. A 69 ft² Cera™ blanket sample was the 6th blanket back from the burner. A 66 ft² Super Wool™ blanket sample was the 7th blanket back from the burner. Another 66 ft² of used ½" Ametek Shrunk Silmat™ (AB50S) was reused to cover the top rear of the pile. At the bottom rear of the pile 125 ft² of BGF™ mat was used. Approximately 170 ft² of chicken wire were used to secure the blankets to the pile. Maintenance time to install the new blanket was 4.5 man-hours.

Decontamination Phase. The test objective was to determine the effectiveness of the decontamination process with a test temperature of 500°F with a 3-hour soak time. During the heat up phase a large amount of steam was noted coming out from underneath the thermal blankets. As the heat up continued the thermal blankets all become discolored, however, they were able to maintain their form and function. Once the pile reached 500°F, the pile was allowed to soak for three hours.

FINAL

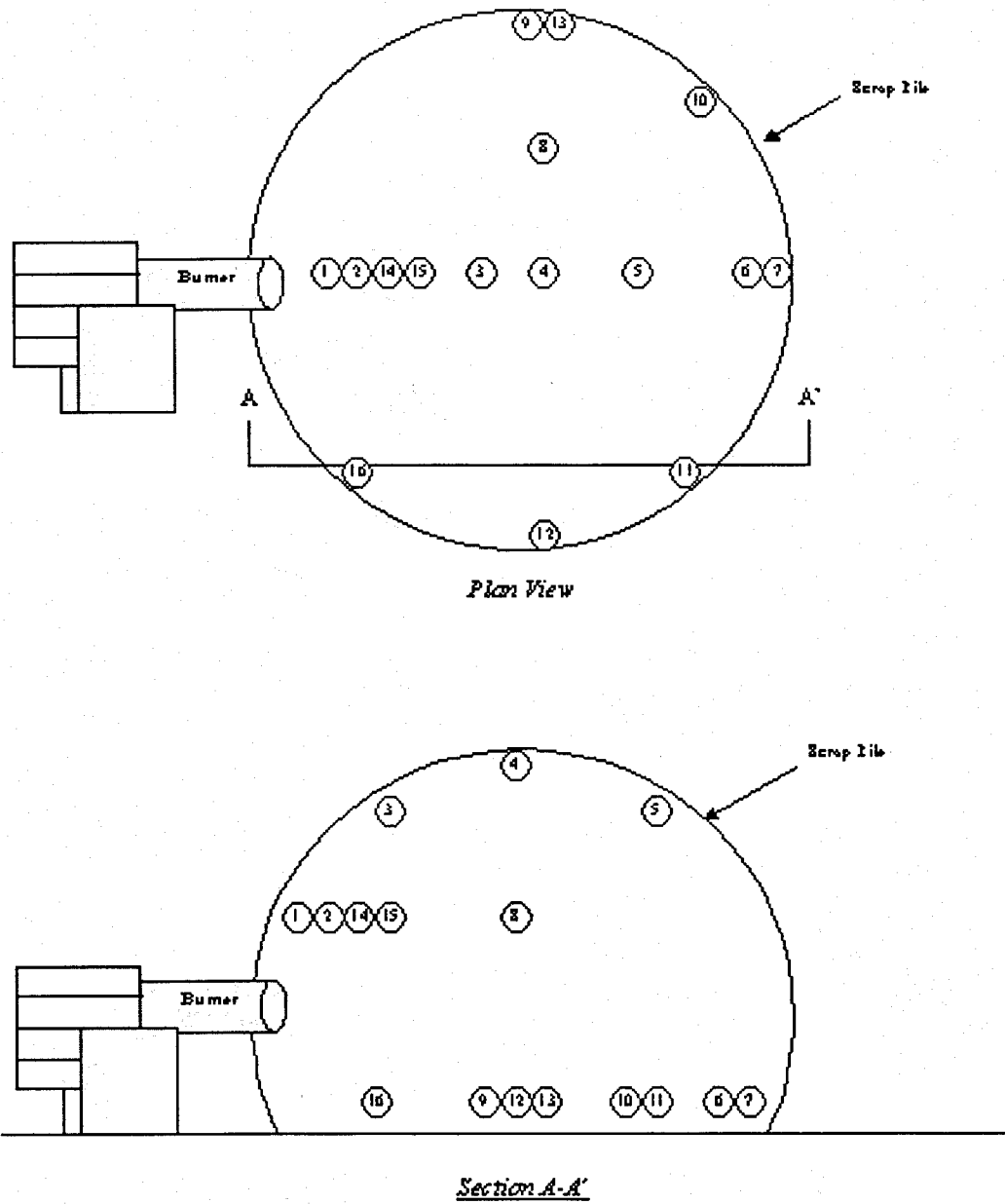


Figure 5.1-6. Thermocouple Locations for Test 6

Test 6 Results

Burner Performance. While attempting to start the burner, a “combustion air fault term 11, combustion air pressure switch PSL101 opened” fault message appeared on the operator’s workstation screen. The computer was shut down and restarted. The fault message did not reappear and testing was continued. Twice the “flame relay reset required” fault appeared on the operator screen. Each time the flame relay was reset the burner started. During the heat up time the burner setpoint override temperature had to be changed several times. It originally started at 1400°F, at 1318 it was changed to 1500°F, at 1645 it was increased to 1550, then at 1715 it was again increased this time to 1575°F, and finally at 1807 the setpoint was set at 1600°F. During cool down at 2044 hours, a “communication failure” appeared on the operator’s workstation screen. Inspection revealed that the generator shut down. Testing was not interrupted because the trial was in the cool down mode.

Thermocouples. During Test 6, the thermocouple signals were transmitted to the operator workstation via wireless remote for recording and decision-making. During the heat up phase two thermocouples had failed, #4 (1156 hrs) and #15 (1358 hrs). By the time these thermocouples had failed they had already reached the predetermined temperature for this trial. Thermocouple #16 was reading over 3300°F before the burner was started and 1046 hours it read 508°F, which is more believable. The readings for #16 were more realistic from 1046 to the end of the trial.

Time and Temperature Summary. The sixth test trial was designed to test the effectiveness of the decontamination process with a test temperature of 500°F with a 3-hour heat soak time. The complete time and temperature data for this trial is located in Appendix B of this report. The time and temperature data for Test 6 are summarized in Table 5.1-11 and 5.1-12.

Table 5.1-11. Time and Temperature Data Summary – Test 6

Event	Date	Start Time	Date	Stop Time	Total Time
Heat-Up	16 Oct 01	10:01	16 Oct 01	17:53	7hr 52min
Soak Time	16 Oct 01	17:53	16 Oct 01	20:53	3hr
Approximate Cool Down Time	16 Oct 01	20:53	16 Oct 01	23:53	3hr

FINAL

Table 5.1-12. Thermocouple Time to 500°F

Thermocouple Number	Date	Heat-up Start Time	Time 500°F was Reached	Actual Temperature	Elapsed Time
1	16 Oct 01	10:01	10:02	604.2	1min
2	16 Oct 01	10:01	10:06	530.8	5min
3	16 Oct 01	10:01	10:06	516.3	5min
4	16 Oct 01	10:01	10:10	506.6	9min
5	16 Oct 01	10:01	10:16	505.2	15min
6	16 Oct 01	10:01	17:01	500.3	7hrs
7	16 Oct 01	10:01	17:10	500.2	7hrs 9min
8	16 Oct 01	10:01	14:02	509.3	4hrs 1min
9	16 Oct 01	10:01	13:26	500.7	3hrs 25min
10	16 Oct 01	10:01	17:53	500.7	7hrs 52min
11	16 Oct 01	10:01	16:47	500.9	6hrs 46min
12	16 Oct 01	10:01	15:06	501.3	5hrs 5min
13	16 Oct 01	10:01	10:33	505.2	32min
14	16 Oct 01	10:01	10:07	513.2	6min
15	16 Oct 01	10:01	10:30	501.0	29min
16*	16 Oct 01	10:01	10:46	508.0	45min

* This is the first accurate reading that was over 500°F.

Results for Test 6 are presented in four graphs as follows:

- Figure 5.1-27 Test 6 System Heatup Performance – Elapsed Time vs. Temperature
- Figure 5.1-28 Test 6 Heatup Time Vs. Temperature for Hottest and Coolest Locations
- Figure 5.1-29 Test 6 Temperature Distribution versus Distance from Burner – Top of Pile
- Figure 5.1-30 Test 6 Temperature Distribution versus Distance from Burner – Bottom Perimeter of Pile

Test 6 System Heatup Performance

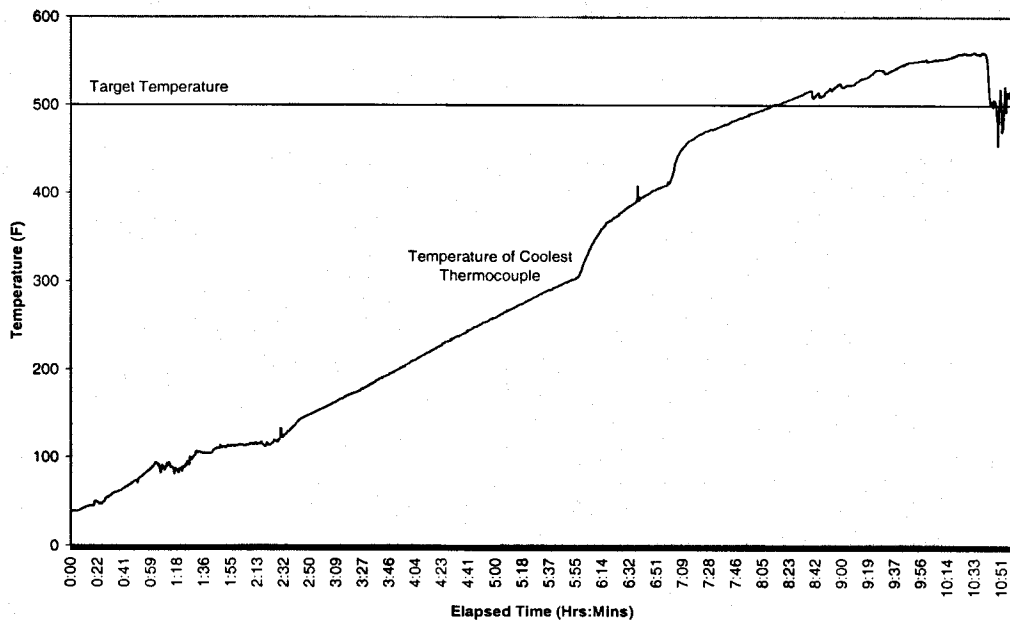


Figure 5.1-27 Test 6 System Heatup Performance – Elapsed Time vs. Temperature

Test 6 Heatup Time Vs. Temperature - Hottest and Coolest Thermocouples

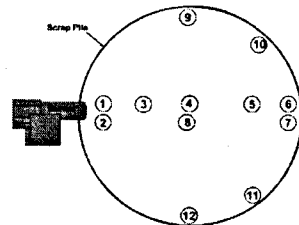
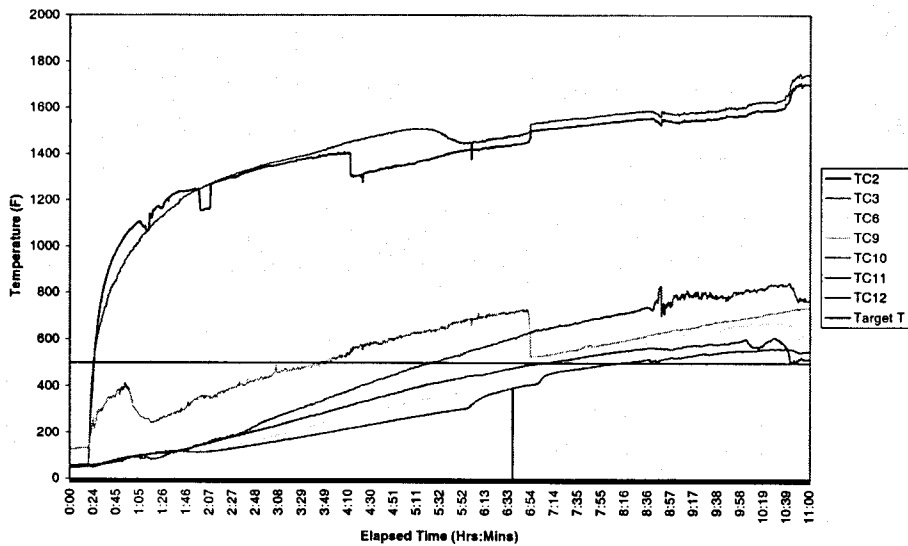


Figure 5.1-28 Test 6 Heatup Time Vs. Temperature for Hottest and Coolest Locations

FINAL

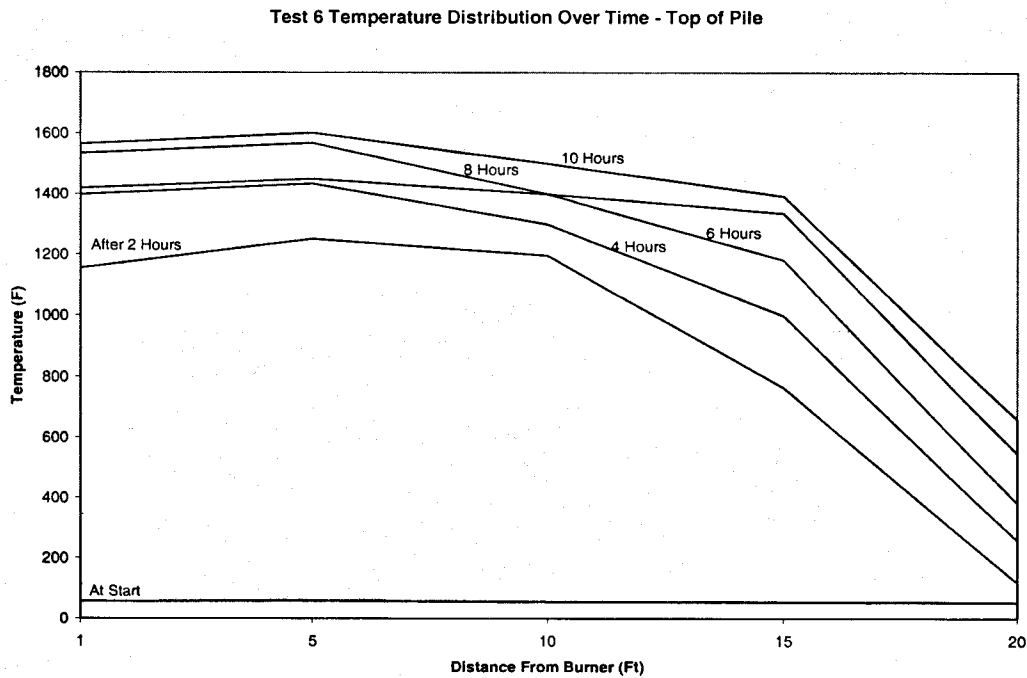


Figure 5.1-29 Test 6 Temperature Distribution versus Distance from Burner – Top of Pile

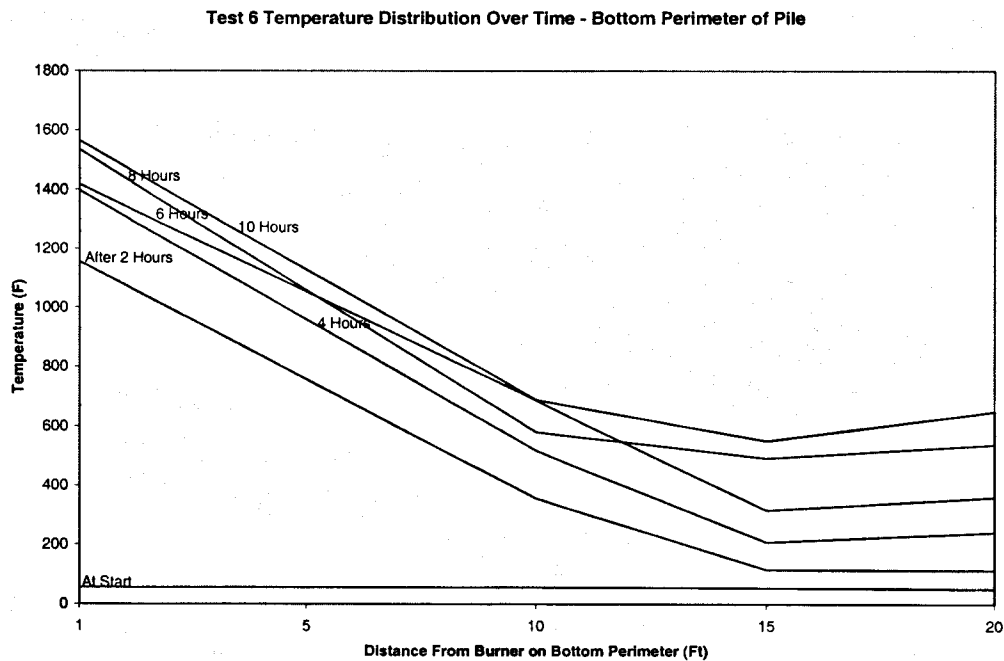


Figure 5.1-30 Test 6 Temperature Distribution versus Distance from Burner – Bottom Perimeter of Pile

Test 6 Burner and Equipment Performance Assessment

During Test 6, the transportable HGD system successfully decontaminated the spiked coupons in the pile in 11 hours of total operating time, including approximately 8 hours heatup time and 3 hours soak time at 500°F (see Section 5.2 for coupon results). The longer total processing time (than previous tests) was the result of the denser scrap in Pile 2 than Pile 1. Pile 2 contained mostly projectile fragments and weighing almost 50 percent more in tonnage than Pile 1 at 20 tons for Pile 2 vs. 14.5 tons for Pile 1.

The hourly processing rate per ton is similar for Pile 1 and Pile 2 at approximately 2 tons per hour. However, the daily processing rate for Pile 2 is higher at 20 tons per day, versus 14.5 tons per day (in consideration of a 12 hour work day for Pile 2 vs. an 8 hour work day for Pile 1). In view of the fact that an 8 hour work day is considered desirable and realistic, a processing rate of 15 tons per day is considered a realistic processing rate for the system.

5.1.7 TEST 7 PERFORMANCE DATA AND ASSESSMENT

Test 7 was conducted on 24 October 2001 with burner ignition taking place at 12:10 PM. The heat soak criteria for the burner system was set at 500°F for 3 hours soak period for Test 7, to collect more data and further validate this criteria as effective. Pile 2 was again used for Test 7 as in Test 6. During Test 7, heavy rainfall was experienced at the test site during mid-test.

Test Preparation. No additional preparation was required for Test 7. No modifications or repairs were required on the HGD system.

Instrumentation – Thermocouples. Thermocouples with temperature transmitters were interlocked to the air heater fuel supply to control the programmed soak temperature of the scrap metal in the pile. The thermocouples were strategically placed at expected cooler locations (near the outside of the pile away from the burner). Prior to testing, it was discovered that nine thermocouples were not reading temperatures properly. It was decided to temporarily repair each of the thermocouples by cutting off the burnt (browned) ends, stripping off all insulation at the ends of the wires and then twisting the two wire ends together.

Burner Control Loop Software Modifications. A revised software program was downloaded into the Operator's Workstation (OW) computer to allow better control of the burner. During Test 7, this program change was tested at the lowest temperature (162°F) with no problems noted. During test #7 it was noted that the high temperature setpoint did not function properly. It would change the override temperature automatically. This high temperature control loop problem was solved by another software change. This procedure took ½ a man-hour. The actual locations of the thermocouples for Test 7 are shown in Figure 5.1-31.

Spiked Coupon Chambers. Twelve spiked coupons chambers, three containing hand grenade fragments, were strategically placed in the pile. The actual locations and analytical results are presented in Section 5.2.

Emissions Monitoring. No emissions sampling was needed or performed for pile #7.

Test Execution – Insulate Pile. Approximately 130 ft² roll of ½ inch unshrunk Silmat™ was placed across the width of the pile in the following locations in order to cover gaps in the pile. A five-foot length was placed at approximately the eighth blanket from the burner. A 22-foot length was placed at approximately the 7th blanket from the burner. A 23-foot length was placed at approximately the 6th blanket from the burner. This procedure took a total of 4.5 man-hours.

FINAL

Decontamination Phase. The test objective was to determine the effectiveness of the decontamination process with an overall pile temperature of 500 °F and a soak time of 3 hours. During Test 7, the first attempt to start the burner failed because the decontamination registers needed to be reset. Initial purging began at 1210 hours, the same time the temperature started recording. The burner start time was 1218 hours.

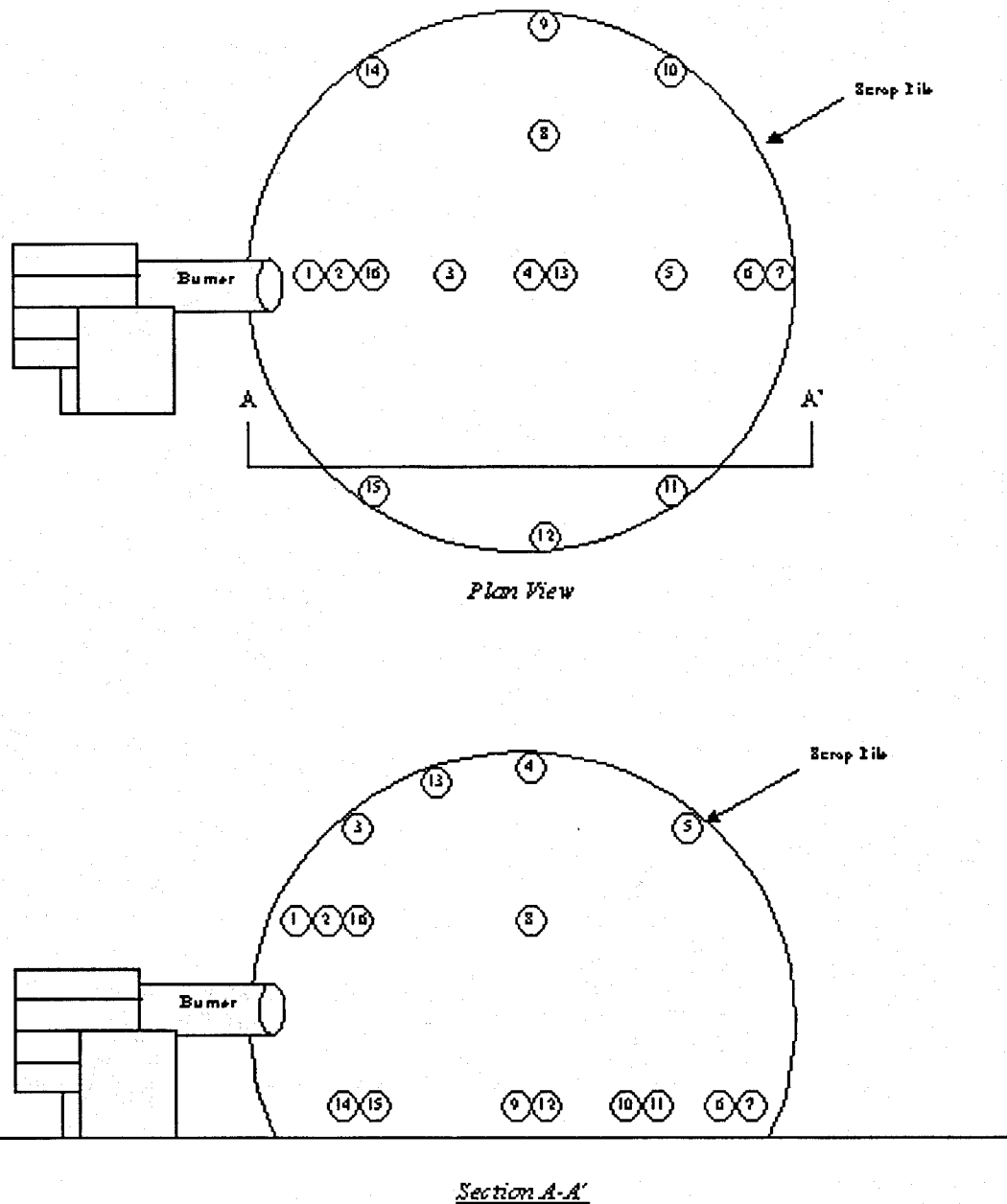


Figure 5.1-31. Thermocouple Location for Test 7

Test 7 Results

Burner Performance. There were multiple shutdowns of the burner during this test run. The first occurred after burner startup when a laptop was connected to the operator's workstation computer. Hauck™ representatives were tuning the control loop during the heat-up operation using a laptop. The burner was then restarted at 1243 hours, however at 1300 hours the registers had to be reset because they were not correct after the burner was stopped at 1243 hours. Another burner shutdown occurred at 1339 hours due to another laptop error. A "PLC latched comm fault" was the error message that was indicated. This error message meant that the register format was being changed in an attempt to correct the irregularity in temperature set points. The Program Logic Controller (PLC) was changing the override temperatures automatically. This was corrected by resetting the setpoints to 500 and 1500°F. After they were reset the burner was purged and then restarted at 1352 hours. At 1525 hours it was noted that the override temperature indicator read an elapsed time of 22:24 minutes, but none of the indicators reached 1500°F. This was an erroneous high temperature trip that required a program change. Between 1808 and 1910 hours the burner control was switched several times from automatic to manual, with the final setting being automatic. At 1905 hours, reconfiguring the shutdown temperature to 1750°F corrected the high temperature control loop problem.

Thermocouples. During Test 7 the thermocouple signals were transmitted to the operator workstation via a wireless remote for recording and decision-making. During the heat up phase the thermocouples indicated when their position reached 500°F. Once all thermocouples reached this temperature the 3-hour soak time started. Some of the thermocouples did lose their signal but nothing that could adversely affect the data. Temperatures started recording at 1210 hours and ended 0036 hours the following day.

Time and Temperature Summary. Test 7 was designed to gather data on the variables of HGD. The test objective was to determine the effectiveness of the decontamination process with a test temperature of 500°F with a 3-hour heat soak time. The complete time and temperature data for this trial is located in Appendix B of this report. Summarized time and temperature results for Test 7 are shown below in Table 5.1-13 and 5.1-14.

Table 5.1-13. Time and Temperature Summary – Test 7

Event	Date	Start Time	Date	Stop Time	Total Time
Heat-Up	24 Oct 01	12:10	24 Oct 01	21:36	9hrs 26min
Soak Time	24 Oct 01	21:36	25 Oct 01	0:36	3hrs
Approximate Cool Down Time	25 Oct 01	0:36	25 Oct 01	3:36	3hr

FINAL

Table 5.1-14. Thermocouple Time to 500 °F

Thermocouple Number	Date	Heat-up Start Time	Time 500°F was Reached	Actual Temperature	Elapsed Time
1	24 Oct 01	12:10	12:20	560.7	10min
2	24 Oct 01	12:10	12:20	582.4	10min
3	24 Oct 01	12:10	12:53	502.2	43min
4	24 Oct 01	12:10	14:31	514.6	2hrs 21min
5	24 Oct 01	12:10	14:38	500.3	2hrs 28min
6	24 Oct 01	12:10	21:17	500.5	9hrs 7min
7	24 Oct 01	12:10	21:11	501.2	9hrs 1min
8	24 Oct 01	12:10	19:37	501.3	7hrs 27min
9	24 Oct 01	12:10	20:50	500.2	8hrs 40min
10	24 Oct 01	12:10	21:20	500.3	9hrs 10min
11	24 Oct 01	12:10	21:25	500.1	9hrs 15min
12	24 Oct 01	12:10	19:44	500	7hr 34 min
13	24 Oct 01	12:10	13:03	503.7	53min
14	24 Oct 01	12:10	21:36	500.7	9hr 26min
15	24 Oct 01	12:10	19:34	529.3	7hr 24min
16	24 Oct 01	12:10	12:20	506.2	10 min

Results for Test 7 are presented in four graphs as follows:

- Figure 5.1-32 Test 7 System Heatup Performance – Elapsed Time vs. Temperature
- Figure 5.1-33 Test 7 Heatup Time Vs. Temperature for Hottest and Coolest Locations
- Figure 5.1-34 Test 7 Temperature Distribution versus Distance from Burner – Top of Pile
- Figure 5.1-35 Test 7 Temperature Distribution versus Distance from Burner – Bottom Perimeter of Pile

Test 7 System Heatup Performance

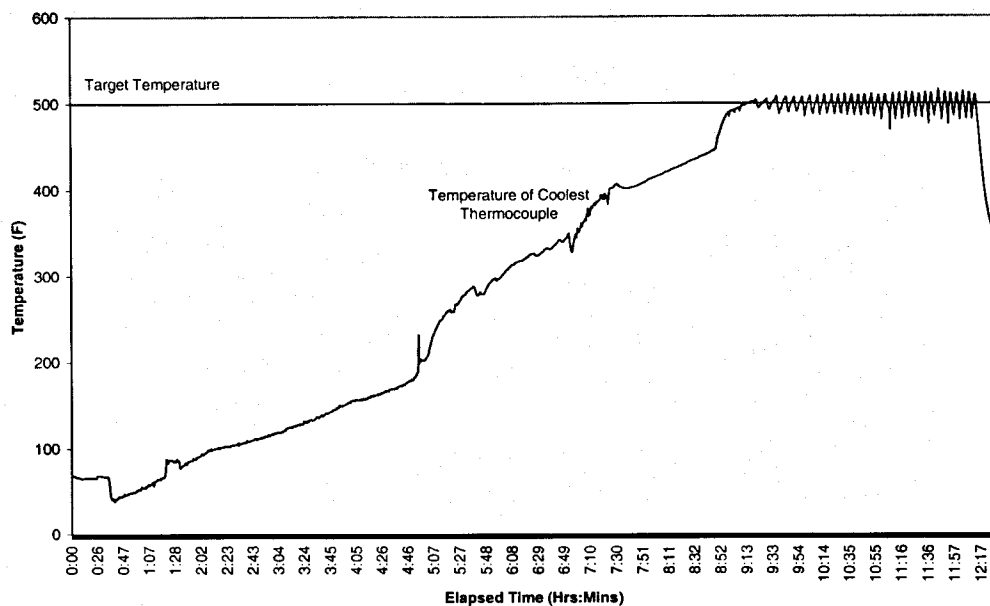


Figure 5.1-32 Test 7 System Heatup Performance – Elapsed Time vs. Temperature

Test 7 Heatup Time Vs Temperature - Hottest and Coolest Locations

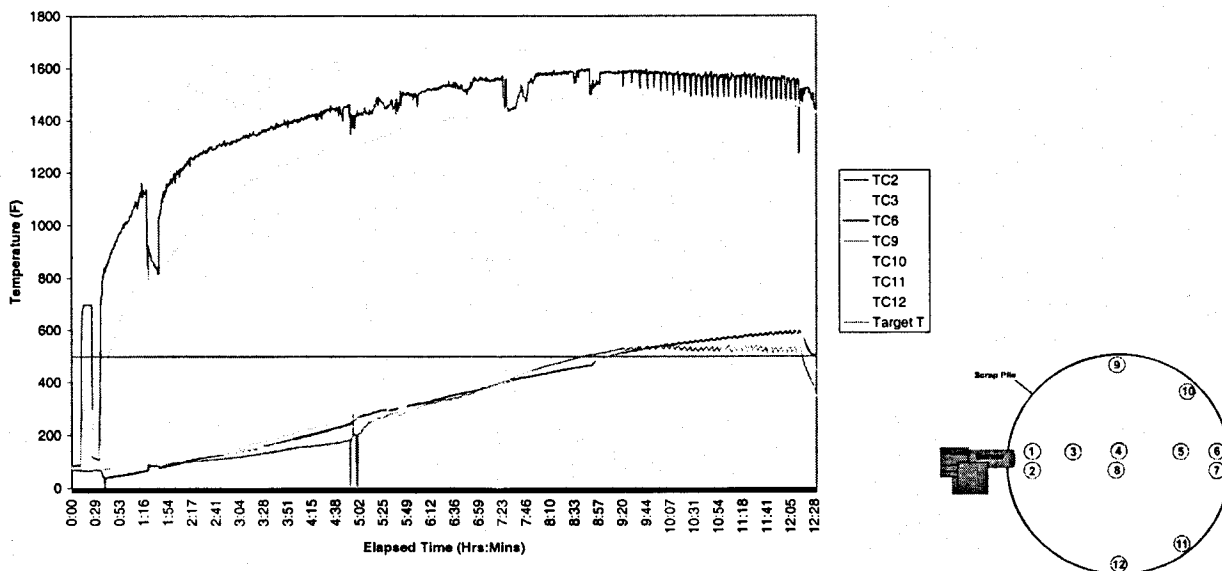


Figure 5.1-33 Test 7 Heatup Time Vs. Temperature for Hottest and Coolest Locations

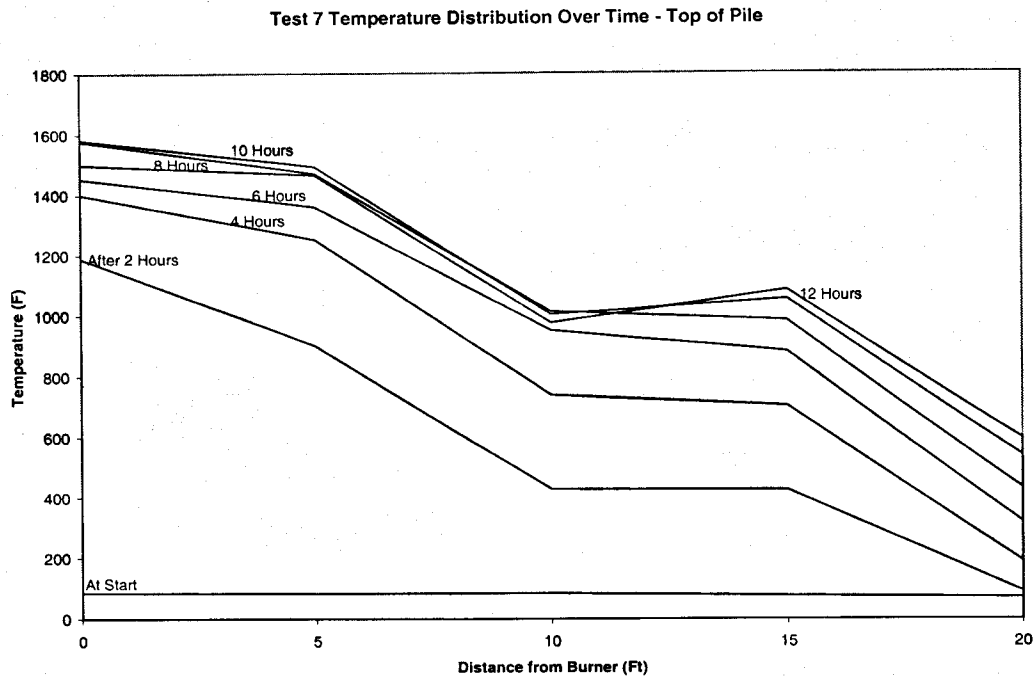


Figure 5.1-34 Test 7 Temperature Distribution versus Distance from Burner – Top of Pile

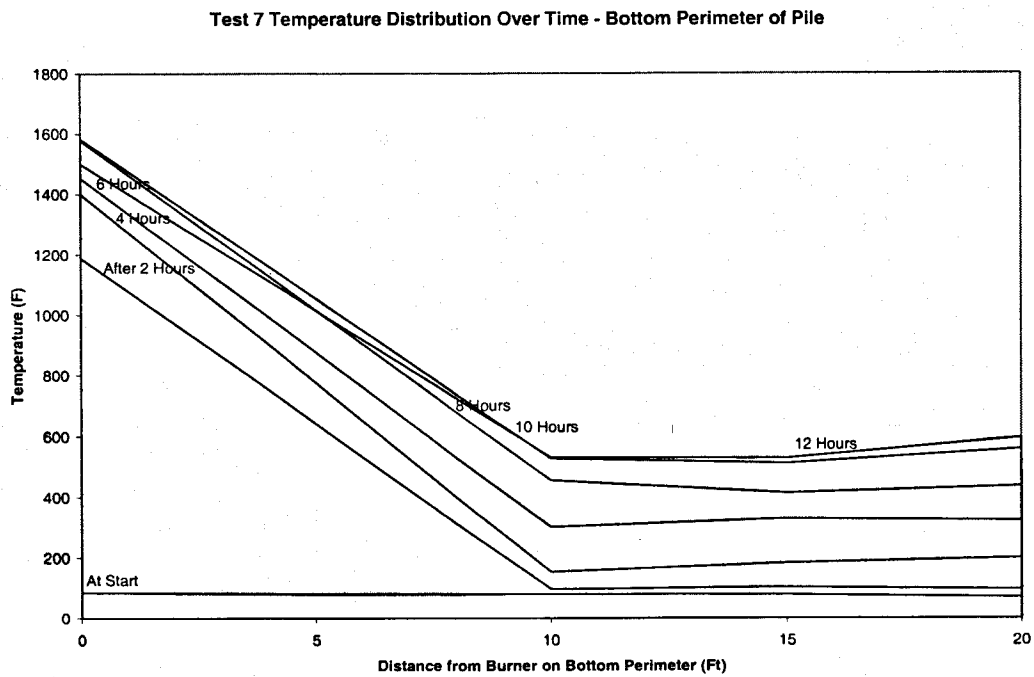


Figure 5.1-35 Test 7 Temperature Distribution versus Distance from Burner – Bottom Perimeter of Pile

Test 7 Burner and Equipment Performance Assessment

During Test 7, the transportable HGD system successfully decontaminated the spiked coupons in the pile in 12-1/2 hours of total operating time, including approximately 9-1/2 hours heatup time and 3 hours soak time at 500°F (see Section 5.2 for coupon results). The longer total processing time (than Test 7 also conducted on Pile 2) was due to heavy rainfall experienced during the test (heat lost to evaporation of rainfall) and burner system outages during the test.

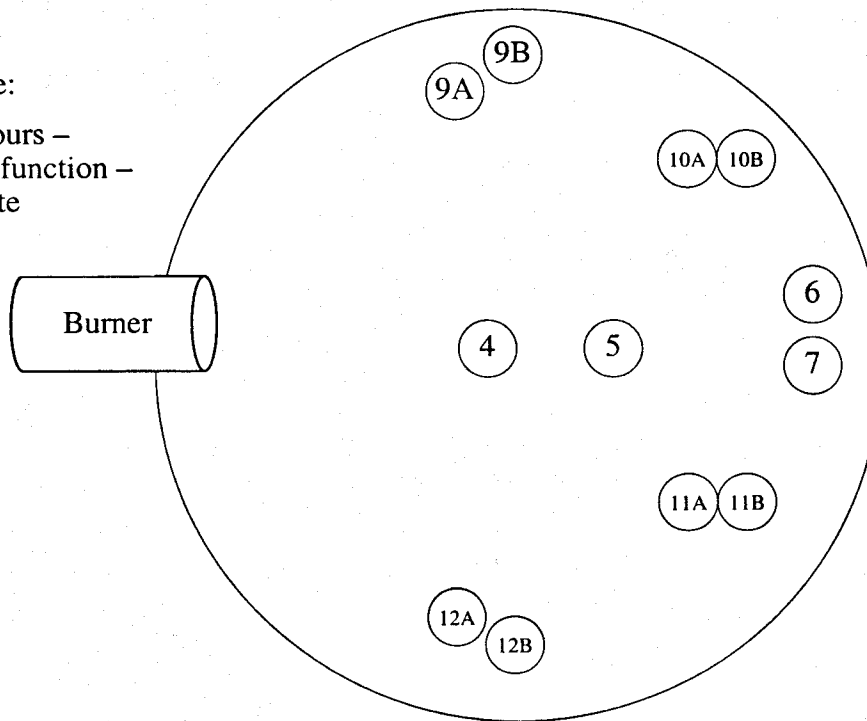
Test 7 proved that the HGD system could be operated in bad weather (heavy rain), with a penalty in terms of extra time (and cost) to operate the system.

5.2 SPIKED COUPONS

Locations and Results. The actual locations for the spiked coupon chambers are shown in Figures 5.2-1 through 5.2-9 and the explosive detection results are shown in Tables 5.2-1 through 5.2-9.

Trial Objective:

600°F for 3 Hours –
Generator Malfunction –
Test Incomplete



KEY

Chambers 7, 11A and 12A contained one hand grenade fragments and one spiked coupons all others only all others contained one spiked coupon.

Figure 5.2-1. Hot Gas Decontamination Spiked Coupons Locations for Test 1

FINAL

Table 5.2-1. Hot Gas Decontamination Results for Test 1

Coupons ^a	HMX (mg)	RDX (mg)	TNT (mg)	Top/ Ground ^b
HGD1-4	<0.001	<0.001	<0.001	Top
HGD1-5	<0.001	<0.001	<0.001	½ up back
HGD1-6	1.11	1.2	0.709	Ground
HGD1-7	1.08	1.13	0.031	Ground
HGD1-9A	1.09	1.18	0.493	Ground
HGD1-9B	1.11	1.19	0.294	Ground
HGD1-10A	1.14	1.22	0.754	Ground
HGD1-10B	1.09	1.04	0.016	Ground
HGD1-11A	1.06	1.05	0.014	Ground
HGD1-11B	1.17	1.21	0.025	Ground
HGD1-12A	1.03	0.015	<0.001	Ground
HGD1-12B	1.06	1.12	0.02	Ground

Calibration	HMX	RDX	TNT
Response Factor x e10			
10 ppm	1.46	1.11	1.39
2.5 ppm	1.38	1.04	1.29
1.0 ppm	1.44	1.1	1.36
0.5 ppm	1.44	1.09	1.34
0.1 ppm	1.69	1.28	1.54
Mean	1.482	1.124	1.384
Std Dev	0.120	0.091	0.094
%Coef vari.	8.10%	8.12%	6.83%

Control	HMX (mg)	RDX (mg)	TNT (mg)
HGD-LCS	1.13	1.21	0.942
Trip Control	1.1	1.16	0.754

Hand Grenade Fragments (Range Scrap)				
HGF-7	0.153	0.893	0.104	Ground
HGF-11A	0.408	2.71	0.13	Ground
HGF-12A	0.354	0.808	0.002	Ground

^a The Coupons are treated with 1.0 ± 0.15 mg of HMX, RDX, and TNT

^b This refers to the location of the coupon or Range Scrap, whether it is on the ground, on top of the pile, or somewhere in between.

FINAL

Test Objective:
600°F for 3 Hours

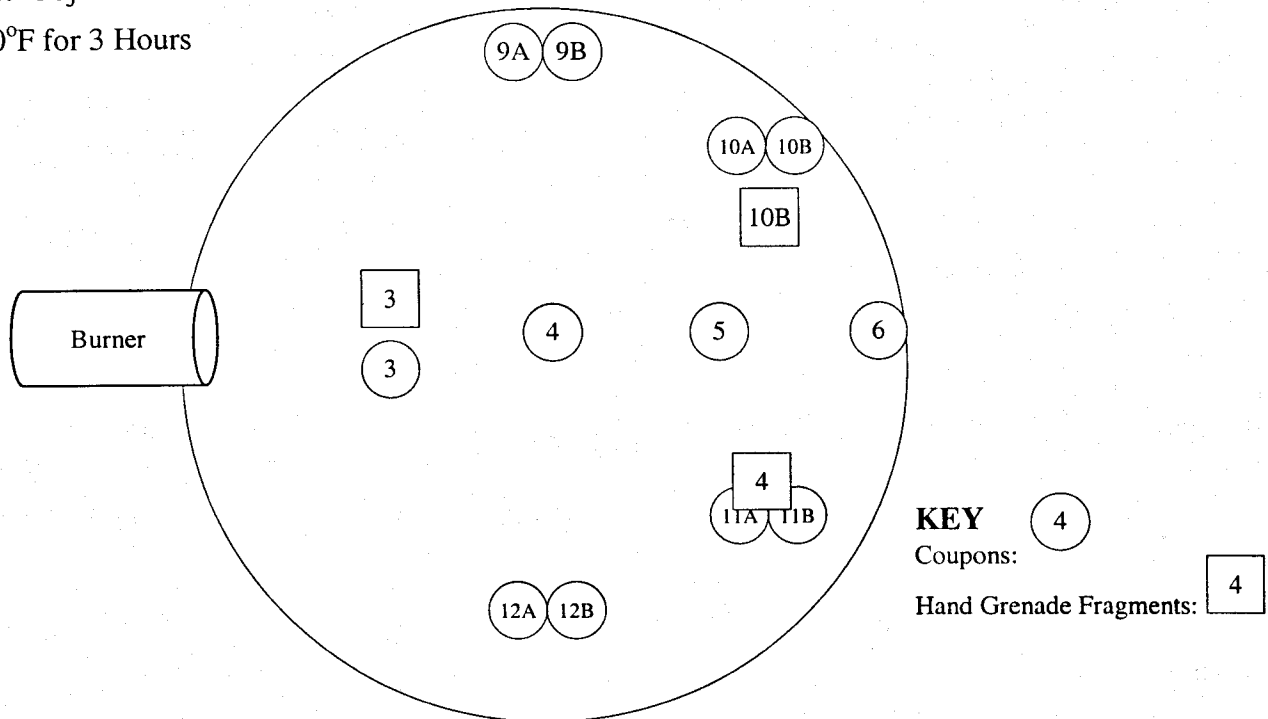


Figure 5.2-2. Spiked Coupons Locations for Test 2

Table 5.2-2. Hot Gas Decontamination Results for Test 2

Coupons ^a	HMX (mg)	RDX (mg)	TNT (mg)	Top/ Ground ^b
HGD2-3	<0.001	<0.001	<0.001	½ up front
HGD2-4	<0.001	<0.001	<0.001	Top
HGD2-5	<0.001	<0.001	<0.001	½ up back
HGD2-6	<0.001	<0.001	<0.001	Ground
HGD2-9A	<0.001	<0.001	<0.001	Ground
HGD2-9B	<0.001	<0.001	<0.001	Ground
HGD2-10A	<0.001	<0.001	<0.001	Ground
HGD2-10B	<0.001	<0.001	<0.001	Ground
HGD2-11A	<0.001	<0.001	<0.001	Ground
HGD2-11B	<0.001	<0.001	<0.001	Ground
HGD2-12A	<0.001	<0.001	<0.001	Ground
HGD2-12B	<0.001	<0.001	<0.001	Ground

Calibration	HMX	RDX	TNT
Response Value x e10			
10 ppm	1.39	1.04	1.16
10 ppm	1.39	1.05	1.17
Mean	1.39	1.04	1.16

Control	HMX (mg)	RDX (mg)	TNT (mg)
HGD-LCS	1.16	1.25	0.953
Trip Control	1.12	1.25	0.795

Hand Grenade Fragments (Range Scrap)				
HGF-3	<0.001	<0.001	<0.001	½ up front
HGF-4	<0.001	<0.001	<0.001	Ground
HGF-10B	<0.001	<0.001	<0.001	Ground

^a The Coupons are treated with 1.0 ± 0.15 mg of HMX, RDX, and TNT

^b This refers to the location of the coupon or Range Scrap, whether it is on the ground, on top of the pile, or somewhere in between.

FINAL

Test Objective:
500°F for 3 Hours

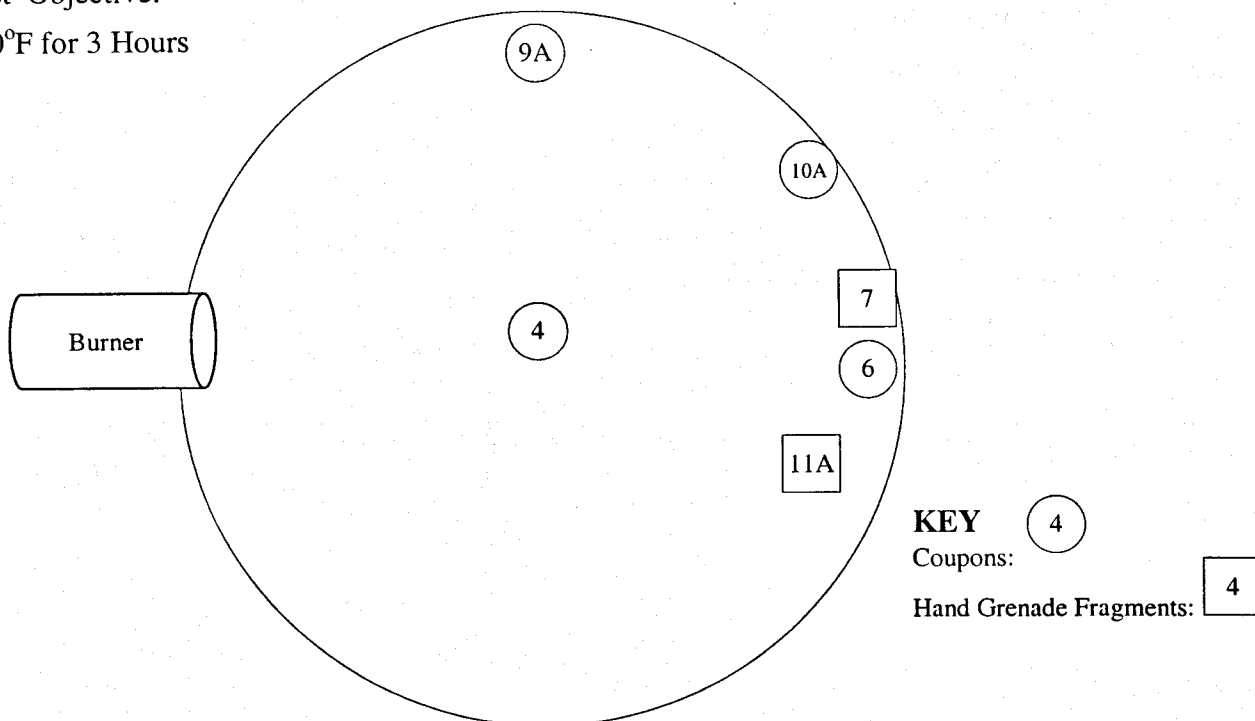


Figure 5.2-3. Spiked Coupons Locations for Test 3^c

^c Date of analysis is September 27, 2001. Analyzed with a Spectra Physic SP-8490.

FINAL

Table 5.2-3. Hot Gas Decontamination Results for Test 3^c

Coupons ^a	HMX (mg)	RDX (mg)	TNT (mg)	Top/ Ground ^b
HGD3-4	<0.001	<0.001	<0.001	Top
HGD3-6	<0.001	<0.001	<0.001	Ground
HGD3-9A	<0.001	<0.001	<0.001	Ground
HGD3-10A	<0.001	<0.001	<0.001	Ground

Hand Grenade Fragments (Range Scrap)				
HGF-7	<0.001	<0.001	<0.001	Ground
HGF-11A	<0.001	<0.001	<0.001	Ground

Calibration	HMX	RDX	TNT
Response Value x e10			
10 ppm	1.03	0.965	1.29
2.5 ppm	1.06	0.996	1.35
1.0 ppm	1.01	0.973	1.29
0.5 ppm	1.02	0.99	1.33
0.1 ppm	0.866	1.2	1.55
Mean	0.9972	1.0248	1.362
Std Dev	0.076	0.099	0.108
%Coef vari.	7.59%	9.63%	7.95%

Control	HMX (mg)	RDX (mg)	TNT (mg)
HGD-LCS	1.2	1.15	0.903
Trip Control	1.23	1.17	0.95

^a The Coupons are treated with 1.0 ± 0.15 mg of HMX, RDX, and TNT

^b This refers to the location of the coupon or Range Scrap, whether it is on the ground, on top of the pile, or somewhere in between.

^c Date of analysis is September 27, 2001. Analyzed with a Spectra Physic SP-8490.

FINAL

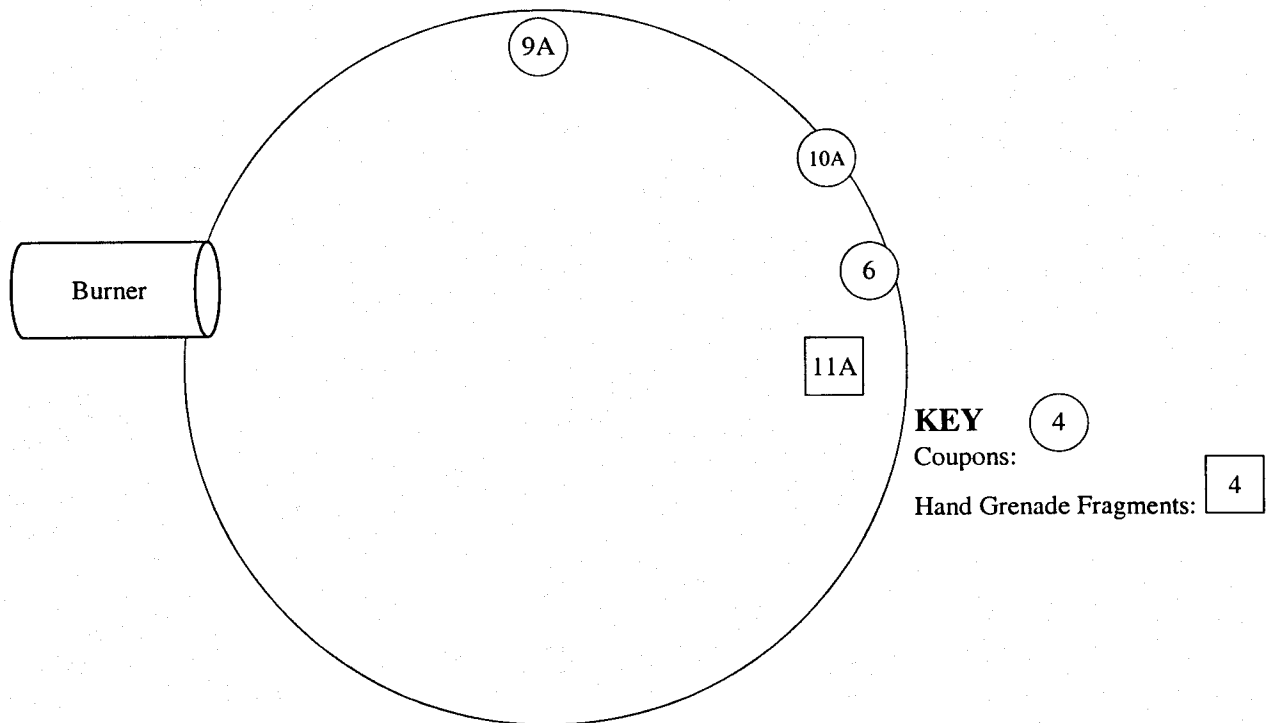


Figure 5.1-4. Spiked Coupons Locations for Test 3^c

Table 5.2-4. Hot Gas Decontamination Results for Test 3^c

Coupons ^a	HMX (mg)	RDX (mg)	TNT (mg)	Top/ Ground ^b
HGD3-6	<0.001	<0.001	<0.001	Ground
HGD3-9A	<0.001	<0.001	<0.001	Ground
HGD3-10A	<0.001	<0.001	<0.001	Ground

Hand Grenade Fragments (Range Scrap)				
HGF-11A	<0.001	<0.001	<0.001	Ground

Calibration	HMX	RDX	TNT
Response Value x e9			
10 ppm	6.46	5.46	7
2.5 ppm	6.4	5.4	6.92
1.0 ppm	6.62	5.46	7.01
0.5 ppm	6.74	5.44	6.99
0.1 ppm	7.23	5.56	7.74
Mean	6.69	5.464	7.132
Std Dev	0.330	0.059	0.342
%Coef vari.	4.93%	1.08%	4.79%

^a The Coupons are treated with 1.0 ± 0.15 mg of HMX, RDX, and TNT

^b This refers to the location of the coupon or Range Scrap, whether it is on the ground, on top of the pile, or somewhere in between.

^c Date of analysis is September 28, 2001. Analyzed with a Spectra SYSTEM UV2000.

FINAL

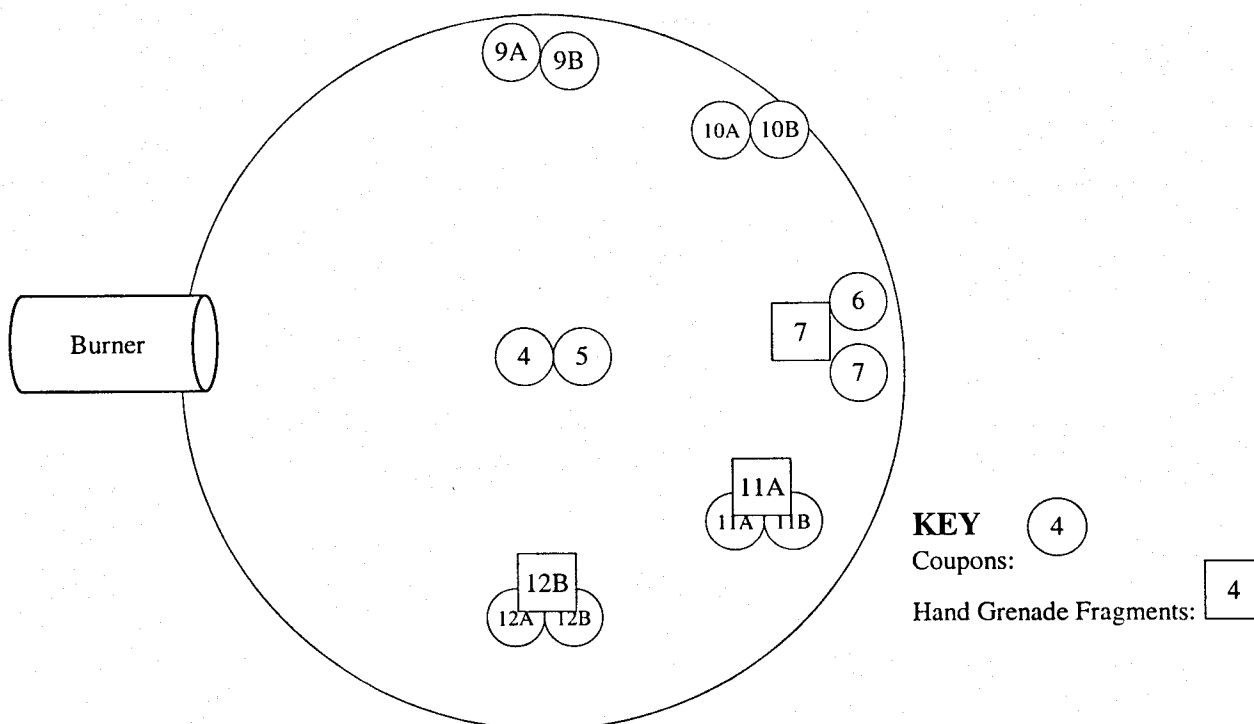


Figure 5.2-5. Spiked Coupons Locations for Test 3^c

Table 5.2-5. Hot Gas Decontamination Results for Test 3^c

Coupons ^a	HMX (mg)	RDX (mg)	TNT (mg)	Top/Ground ^b
HGD3-4	<0.001	<0.001	<0.001	Top
HGD3-5	<0.001	<0.001	<0.001	Top
HGD3-6	<0.001	<0.001	<0.001	Ground
HGD3-7	<0.001	<0.001	<0.001	Ground
HGD3-9A	<0.001	<0.001	<0.001	Ground
HGD3-9B	<0.001	<0.001	<0.001	Ground
HGD3-10A	<0.001	<0.001	<0.001	Ground
HGD3-10B	<0.001	<0.001	<0.001	Ground
HGD3-11A	<0.001	<0.001	<0.001	Ground
HGD3-11B	<0.001	<0.001	<0.001	Ground
HGD3-12A	<0.001	<0.001	<0.001	Ground
HGD3-12B	<0.001	<0.001	<0.001	Ground

Calibration	HMX	RDX	TNT
Response Value x e10			
1.0 ppm	1.03	0.955	1.31
1.0 ppm	1.02	0.946	1.31
Mean	1.025	0.9505	1.31

Control	HMX (mg)	RDX (mg)	TNT (mg)
HGD-LCS	1.21	1.26	0.977
Trip Control	1.01	1.07	0.817
Trip Blank	<0.001	<0.001	<0.001

Hand Grenade Fragments (Range Scrap)

HGF-7	<0.001	<0.001	<0.001	Ground
HGF-11A	<0.001	<0.001	<0.001	Ground
HGF-12A	<0.001	<0.001	<0.001	Ground

^a The Coupons are treated with 1.0 ± 0.15 mg of HMX, RDX, and TNT

^b This refers to the location of the coupon or Range Scrap, whether it is on the ground, on top of the pile, or somewhere in between.

^c Date of analysis is September 24, 2001. Analyzed with a Spectra Physics SP-8490.

FINAL

Trial Objective:
500°F for 2 Hours

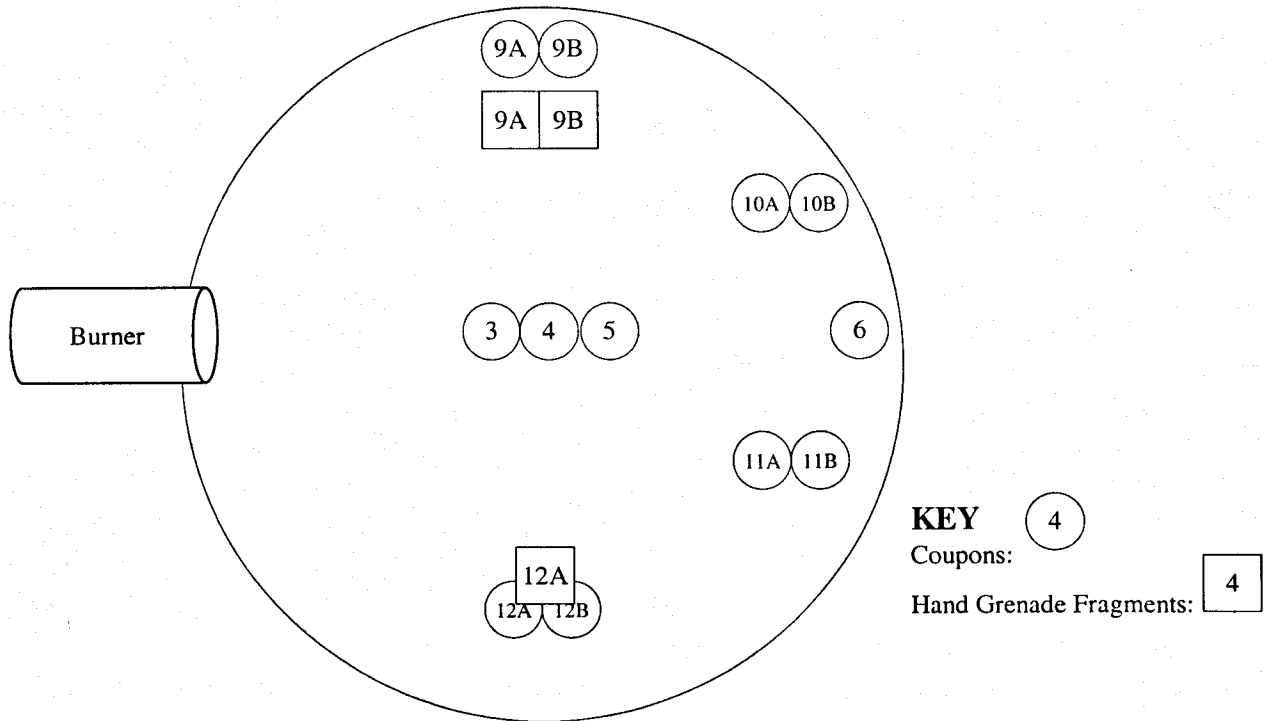


Figure 5.2-6. Hot Gas Decontamination Spiked Coupons Locations for Test 4

Table 5.2-6. Hot Gas Decontamination Results for Test 4

Coupons ^a	HMX (mg)	RDX (mg)	TNT (mg)	Top/ Ground ^b
HGD4-3	<0.001	<0.001	<0.001	Top
HGD4-4	<0.001	<0.001	<0.001	Top
HGD4-5	<0.001	<0.001	<0.001	Top
HGD4-6	<0.001	<0.001	<0.001	Ground
HGD4-9A	0.372	<0.001	<0.001	Ground
HGD4-9B	0.81	<0.001	<0.001	Ground
HGD4-10A	0.018	<0.001	<0.001	Ground
HGD4-10B	<0.001	<0.001	<0.001	Ground
HGD4-11A	<0.001	<0.001	<0.001	Ground
HGD4-11B	<0.001	<0.001	<0.001	Ground
HGD4-12A	<0.001	<0.001	<0.001	Ground
HGD4-12B	<0.001	<0.001	<0.001	Ground

Calibration	HMX	RDX	TNT
Response Value x e10			
1.0 ppm	1.05	0.974	1.32
1.0 ppm	1.1	1.02	1.39
Mean	1.08	0.997	1.36

Control	HMX (mg)	RDX (mg)	TNT (mg)
HGD-LCS	1.12	1.15	0.886
Trip Control	1.17	1.22	0.915
Trip Blank	<0.001	<0.001	<0.001

Hand Grenade Fragments (Range Scrap)

HGF-9A	0.011	<0.001	<0.001	Ground
HGF-9B	0.197	0.031	<0.001	Ground
HGF-12A	<0.001	<0.001	<0.001	Ground

^a The Coupons are treated with 1.0 ± 0.15 mg of HMX, RDX, and TNT

^b This refers to the location of the coupon or Range Scrap, whether it is on the ground, on top of the pile, or somewhere in between.

FINAL

Trial Objective:
600°F for 2 Hours

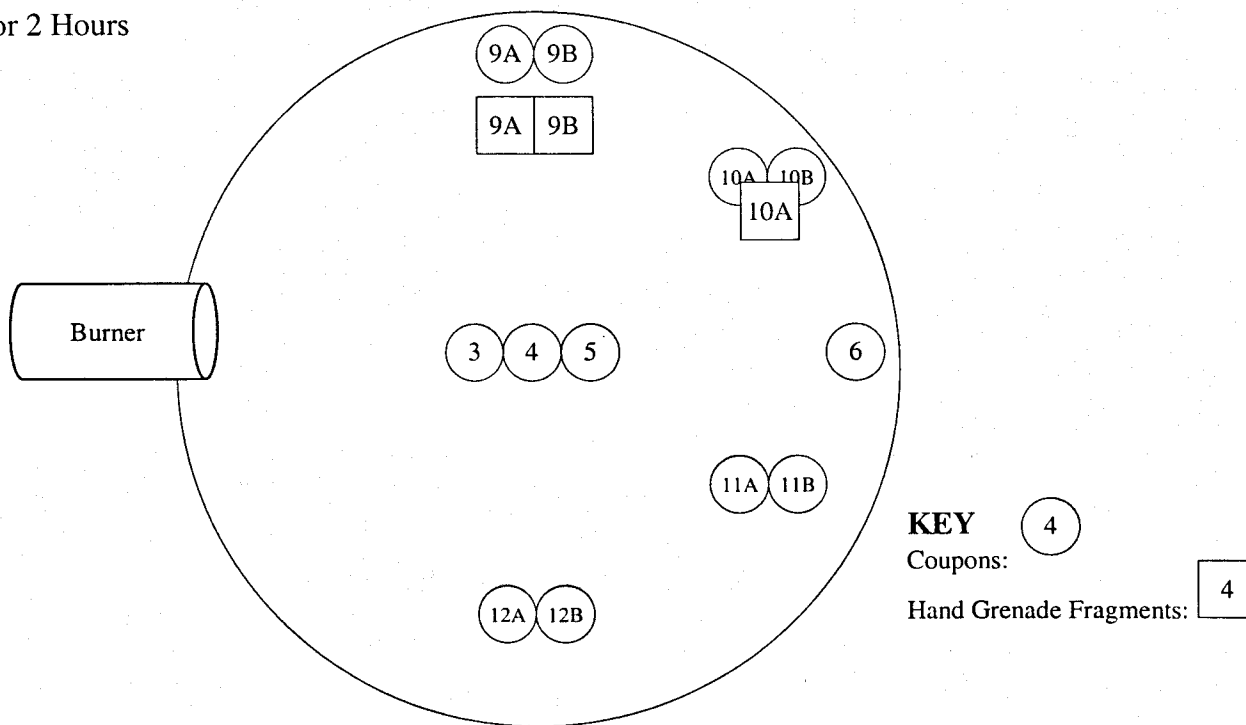


Figure 5.2-7. Hot Gas Decontamination Spiked Coupons Locations for Test 5

Table 5.2-7. Hot Gas Decontamination Results for Test 5

Coupons ^a	HMX (mg)	RDX (mg)	TNT (mg)	Top/Ground ^b
HGD5-3	<0.001	<0.001	<0.001	Top
HGD5-4	<0.001	<0.001	<0.001	Top
HGD5-5	<0.001	<0.001	<0.001	Top
HGD5-6	<0.001	<0.001	<0.001	Ground
HGD5-9A	<0.001	<0.001	<0.001	Ground
HGD5-9B	<0.001	<0.001	<0.001	Ground
HGD5-10A	<0.001	<0.001	<0.001	Ground
HGD5-10B	<0.001	<0.001	<0.001	Ground
HGD5-11A	<0.001	<0.001	<0.001	Ground
HGD5-11B	<0.001	<0.001	<0.001	Ground
HGD5-12A	<0.001	<0.001	<0.001	Ground
HGD5-12B	<0.001	<0.001	<0.001	Ground

Calibration	HMX	RDX	TNT
Response Value x e10			
1.0 ppm	1.01	0.943	1.22
1.0 ppm	1.04	0.928	1.18
Mean	1.02	0.932	1.2

Control	HMX (mg)	RDX (mg)	TNT (mg)
HGD-LCS	1.17	1.2	0.929
Trip Control	1.15	1.16	0.842
Trip Blank	<0.001	<0.001	<0.001

Hand Grenade Fragments (Range Scrap)				
HGF-9A	<0.001	<0.001	<0.001	Ground
HGF-9B	<0.001	<0.001	<0.001	Ground
HGF-10A	<0.001	<0.001	<0.001	Ground

^a The Coupons are treated with 1.0 ± 0.15 mg of HMX, RDX, and TNT

^b This refers to the location of the coupon or Range Scrap, whether it is on the ground, on top of the pile, or somewhere in between.

FINAL

Trial Objective:
500°F for 3 Hours

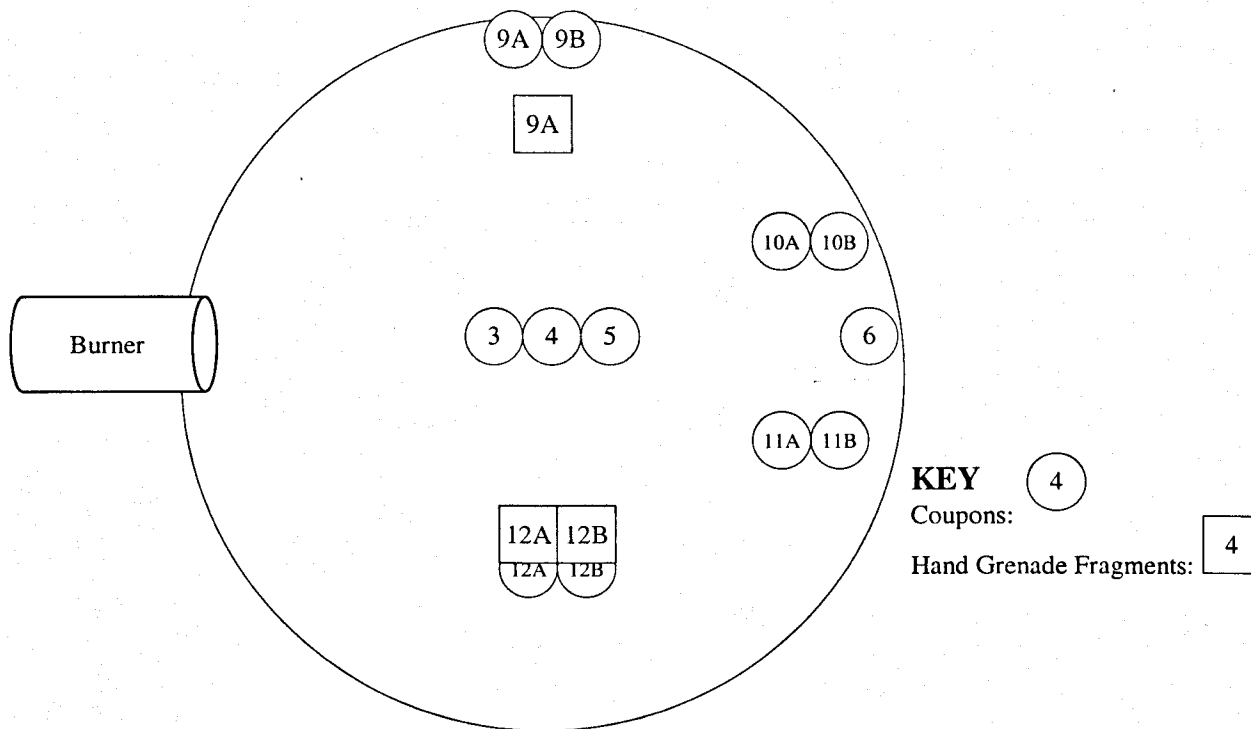


Figure 5.2-8. Spiked Coupons Locations for Test 6

Table 5.2-8. Hot Gas Decontamination Results for Test 6

Coupons ^a	HMX (mg)	RDX (mg)	TNT (mg)	Top/Ground ^b
HGD6-3	<0.001	<0.001	<0.001	Top
HGD6-4	<0.001	<0.001	<0.001	Top
HGD6-5	<0.001	<0.001	<0.001	Top
HGD6-6	<0.001	<0.001	<0.001	Ground
HGD6-9A	<0.001	<0.001	<0.001	Ground
HGD6-9B	<0.001	<0.001	<0.001	Ground
HGD6-10A	<0.001	<0.001	<0.001	Ground
HGD6-10B	<0.001	<0.001	<0.001	Ground
HGD6-11A	<0.001	<0.001	<0.001	Ground
HGD6-11B	<0.001	<0.001	<0.001	Ground
HGD6-12A	<0.001	<0.001	<0.001	Ground
HGD6-12B	<0.001	<0.001	<0.001	Ground

Calibration	HMX	RDX	TNT
Response Value x e10			
1.0 ppm	1.01	0.965	1.33
1.0 ppm	0.99	0.961	1.33
Mean	1	0.963	1.33

Control	HMX (mg)	RDX (mg)	TNT (mg)
HGD-LCS	1.16	1.18	0.902
Trip Control	1.16	1.14	1.08
Trip Blank	<0.001	<0.001	<0.001

Hand Grenade Fragments (Range Scrap)				
HGF-9A	<0.001	<0.001	<0.001	Ground
HGF-12A	<0.001	<0.001	<0.001	Ground
HGF-12B	<0.001	<0.001	<0.001	Ground

^a The Coupons are treated with 1.0 ± 0.15mg of HMX, RDX, and TNT

^b This refers to the location of the coupon or Range Scrap, whether it is on the ground, on top of the pile, or somewhere in between.

FINAL

Trial Objective:
500°F for 3 Hours

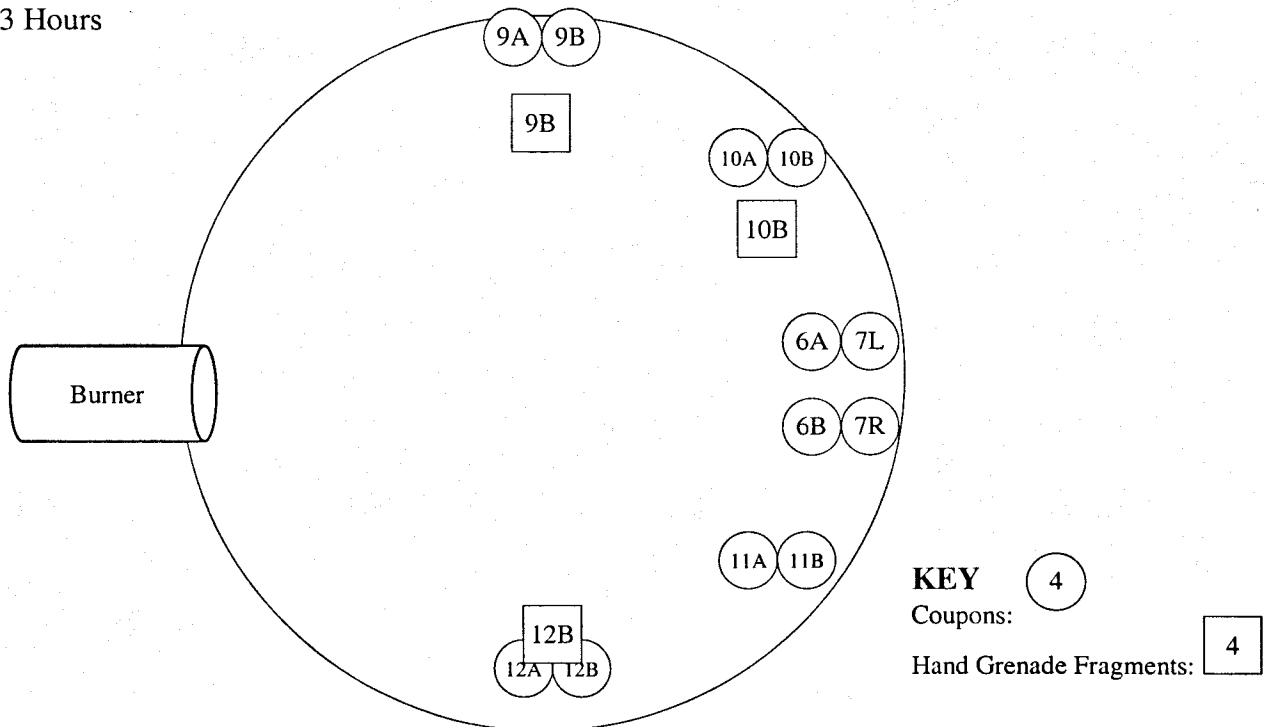


Figure 5.2-9. Hot Gas Decontamination Spiked Coupons Locations for Test 7

Table 5.2-9. Hot Gas Decontamination Results for Test 7

Coupons ^a	HMX (mg)	RDX (mg)	TNT (mg)	Top/Ground ^b
HGD7-6A	<0.001	<0.001	<0.001	Ground
HGD7-6B	<0.001	<0.001	<0.001	Ground
HGD7-7L	<0.001	<0.001	<0.001	Ground
HGD7-7R	<0.001	<0.001	<0.001	Ground
HGD7-9A	<0.001	<0.001	<0.001	Ground
HGD7-9B	<0.001	<0.001	<0.001	Ground
HGD7-10A	<0.001	<0.001	<0.001	Ground
HGD7-10B	<0.001	<0.001	<0.001	Ground
HGD7-11A	<0.001	<0.001	<0.001	Ground
HGD7-11B	<0.001	<0.001	<0.001	Ground
HGD7-12A	<0.001	<0.001	<0.001	Ground
HGD7-12B	<0.001	<0.001	<0.001	Ground

Hand Grenade Fragments (Range Scrap)				
HGF-9B	<0.001	<0.001	<0.001	Ground
HGF-10B	<0.001	<0.001	<0.001	Ground
HGF-12B	<0.001	<0.001	<0.001	Ground

Calibration	HMX	RDX	TNT
Response Value x e10			
1.0 ppm	4.03	3.13	4.27
1.0 ppm	3.95	3.32	4.28
Mean	3.99	3.22	4.28

Control	HMX (mg)	RDX (mg)	TNT (mg)
HGD-LCS	1.06	1.18	0.914
Trip Control	0.932	1.07	0.917
Trip Blank	<0.001	<0.001	<0.001

^a The Coupons are treated with 1.0 ± 0.15 mg of HMX, RDX, and TNT

^b This refers to the location of the coupon or Range Scrap, whether it is on the ground, on top of the pile, or somewhere in between.

Note: Following 7th trial chambers were lost in shipment for 12 days.

FINAL

Scrap Metal Results. Prior to covering the first test pile, eleven samples (surface wipes, and small pieces scraped from surfaces) were collected from the range scrap pile. Most of the samples were taken from surfaces that gave a positive response to Expray® kit wipe samples (second can "Nitramines/nitrate esters"). The acquisition method, a description of the scrap and the field explosive detection data are presented in Table 5.2-10.

Testing using Expray works in the following manner:

Step 1. Slide one collection paper from the Grey dispenser (#00520). The collection paper is hermetically sealed to prevent either pre- or cross contamination.

Step 2. Peel the protective silicon layer exposing the collection surface. Be sure not to touch the exposed the adhesive collection surface, thus, avoiding contamination.

Step 3. Wipe the suspected area (e.g. objects, hands, etc.) Or touch suspected substance with the collection paper

Step 4. Shake the Expray-1 can before spraying.

Step 5. Spray the Expray-1 can briefly and away from body onto the # 00520 test paper from a distance of approximately 10-cm (4 inches).

Step 6. Observe for an immediate dark brown color reaction similar to the color of the letter E on the Expray-1 can label. A positive reaction indicate the presence of group A (TNT, TNB, etc.) explosive residues on the paper.

Step 7. Next, Shake and Spray the Expray-2 onto the same test paper from a distance of approximately 10 cm (4 inches).

Step 8. Observe for an immediate pink color reaction similar to the color of the letter X on the Expray-2 can label. A positive reaction indicates the presence of group B (Semtex, RDX, PETN etc.) explosive residues on the paper.

Step 9. Next, Shake well and Spray the Expray-2 onto the same test paper from a distance of approximately 10-cm (4 inches).

Step 10. Observe for an immediate pink color reaction similar to the color of the letter I on the Expray-2 can label. A positive reaction indicates the presence of Nitrate containing substance residues on the paper.

FINAL

Table 5.2-10. Explosive Detection On Range Scrap

Sample Label	Acquisition Method	Description of Item	Explosives Detected using Expray®
B1	Q-Tip Wipe	Metal Disk Used To Fill 155mm Inert Round	No
B2	Q-Tip Wipe	Reactive Armor Tile Cover	Yes
B3	Q-Tip Wipe	Reactive Armor Tile Cover	Yes
B4	Q-Tip Wipe	Reactive Armor Tile Cover	Yes
B5	Q-Tip Wipe	Inside of 250 lb Inert Filled Bomb	No
B6	Q-Tip Wipe	Reactive Armor Tile Cover White Range Residue/Paint On Surface	Yes
B7	Paint Scraped Off Surface	Piece Of White Range Residue	No
B8	Q-Tip Wipe	Reactive Armor Test Box, Black Coated White Residue/Paint On Surface	Yes
B9	Q-Tip Wipe	Reactive Armor Test Box, Black Coated White Residue/Paint On Surface	Yes
B10	Paint Scraped Off Surface	Piece Of Black Coated White Range Residue	No
B11	Q-Tip Wipe	Witness Plate	No

The eleven samples were further analyzed for explosive residues using EPA Method 8330 HPLC which frequently established the presence of NG, TNT, RDX and HMX. The results of the analyses are presented in Table 5.2-11.

FINAL

Table 5.2-11. Explosives Detected On Scrap

Sample Label	NG (mg/L)	TNT (mg/L)	RDX (mg/L)	HMX (mg/L)
B1	ND	0.08	ND	ND
B2	ND	0.01	530	9.5
B3	1.1	ND	2.4	14
B4	ND	ND	27	8.7
B5	ND	0.10	59	10
B6	ND	0.06	86	12
B7	ND	ND	25	ND
B8	ND	ND	0.66	11
B9	0.6	ND	ND	11
B10	ND	ND	ND	ND
B11	0.6	ND	ND	5.5

In summary, the eleven samples that were collected from the range pile, just prior to the first trial indicated the presence of nitroamines and nitrate esters. Further analysis by RP-HPLC-UV established the presence of NG, TNT, RDX, and HMX residues within the range scrap.

At the conclusion of Test 2, seven scrap samples were removed from the pile. Surface wipes and small pieces of material were taken from the pieces of scrap. Note: The first test trial did not get to complete the heat-up process and the analysis of the exposed spiked coupons concluded that explosives were still present. Thus, it was further concluded that explosives still existed on the range scrap in the pile prior to Test 2. Of the seven samples taken from the range scrap after the second trial, only one piece of military web strap showed residues of 0.74 mg/L of RDX and 0.86 mg/L of HMX still existed. The analysis of the 5 pieces of metallic scrap and one piece of gasket material revealed that no explosives were detected. Note: During the several inspection processes care was taken to remove any non-metallic items from the test piles, but as shown a military web strap was commingled into the pile and was not decontaminated during the process. Military web straps should be added to the technology limitations.

Samples were obtained from piles of scrap that would be used in trials 6 and 7. Analysis of the samples from the untreated metal scrap piles by RP-HPLC-UV established the presence of RDX and HMX.

At the completion of the 7th HGD Test, eight pieces of scrap were removed from the pile. Samples were taken from the scrap with cotton balls that had been moistened with 1-2 mL of acetone. The acquisition method, a description of the scrap and the field explosive detection data are presented in Table 5.2-12.

FINAL

Table 5.2-12. Explosive Detection On Range Scrap

Sample Label	Acquisition Method	Description of Item	Explosives Detected using Expray®
7-1	Cotton ball & acetone	Inside 155-mm round, near bottom of pile at 6:00	No explosives detected
7-2	Cotton ball & acetone	Inside 155-mm round, near bottom of pile at 6:00	No explosives detected
7-3	Cotton ball & acetone	Inside large bomb at 9:00	No explosives detected
7-4	Cotton ball & acetone	Surface of plate at 11:00	No explosives detected
7-5	Cotton ball & acetone	Inside 155mm round at 3:00	No explosives detected
7-6	Cotton ball & acetone	Armor plate at 3:00	No explosives detected
7-7	Cotton ball & acetone	Pipe surface at 3:00	No explosives detected
7-8	Cotton ball & acetone	Armor plate at 6:00	No explosives detected

The eight samples were further analyzed for explosive residues using EPA Method 8330 HPLC which frequently established the presence of TNT, RDX and HMX. The sample area swabbed was approximately 100 cm² (10 cm x 10 cm). Specifically the cotton balls were air dried then extracted with 10 mL of acetonitrile. The analysis of the eight samples revealed that no explosives were detected.

5.3 EMISSIONS RESULTS

Continuous Emission Monitoring: Result showed that the highest concentrations found belonged to CO₂ in all three cases. Table 5.3-1 below summarizes the results for each test run. These results are based on the average value for the entire run time. Figures 5.3-1 through 5.3-6 show real time results for the August 16, 2001 test run. Figures 5.3-7 through 5.3-11 give real time results for the September 5, 2001 test run, while Figures 5.3-12 through 5.3-19 show real time results for the October 16, 2001 test run. The real time results were recorded at approximately every six seconds. The highest recorded value for CO₂ was 1791.3 ppm. That occurred during the September 5, 2001 test 10 hours and 47 minutes after startup.

FINAL

Table 5.3-1. Inorganic Gas Concentrations Summary

TARGET ANALYTE	CAS NUMBER	CONCENTRATION (PPM)	TOTAL SAMPLING TIME	TLV ^A (PPM)
		Time Weighted Averages		
Test 1	16 Aug 01			
SO ₂	7446-09-5	0.00	21	2
CO	630-08-0	0.62	21	25
CO ₂	124-38-9	414	21	5000
NO _x	Variable ^b	0.9	21	Ceiling ^c 3
Test 2	5 Sept 01			
SO ₂	7446-09-5	0.00	25	2
CO	630-08-0	0.004	25	25
CO ₂ (0-1000ppm)	124-38-9	487	25	5000
CO ₂ (0-5000ppm)	124-38-9	540	25	5000
NO _x	Variable ^b	1.2	25	Ceiling ^c 3
Test 6	16 Oct 01			
SO ₂	7446-09-5	0.003	25	2
CO	630-08-0	0.125	25	25
CO ₂ (0-1000ppm)	124-38-9	387	25	5000
CO ₂ (0-5000ppm)	124-38-9	348	25	5000
NO _x	Variable ^b	0.6	25	Ceiling ^c 3

^a TWA taken from: American Conference of Government Industrial Hygienists, Threshold Limit Values for Chemical Substances and Physical Agents and Biological Indices, 2001.

^b NO_x is the combination of various compounds. The most common type is NO₂. This has a CAS number of 10102-44-0.

^c Value denotes TLV – ceiling defined as the concentration that should not be exceeded during any part of the working exposure.

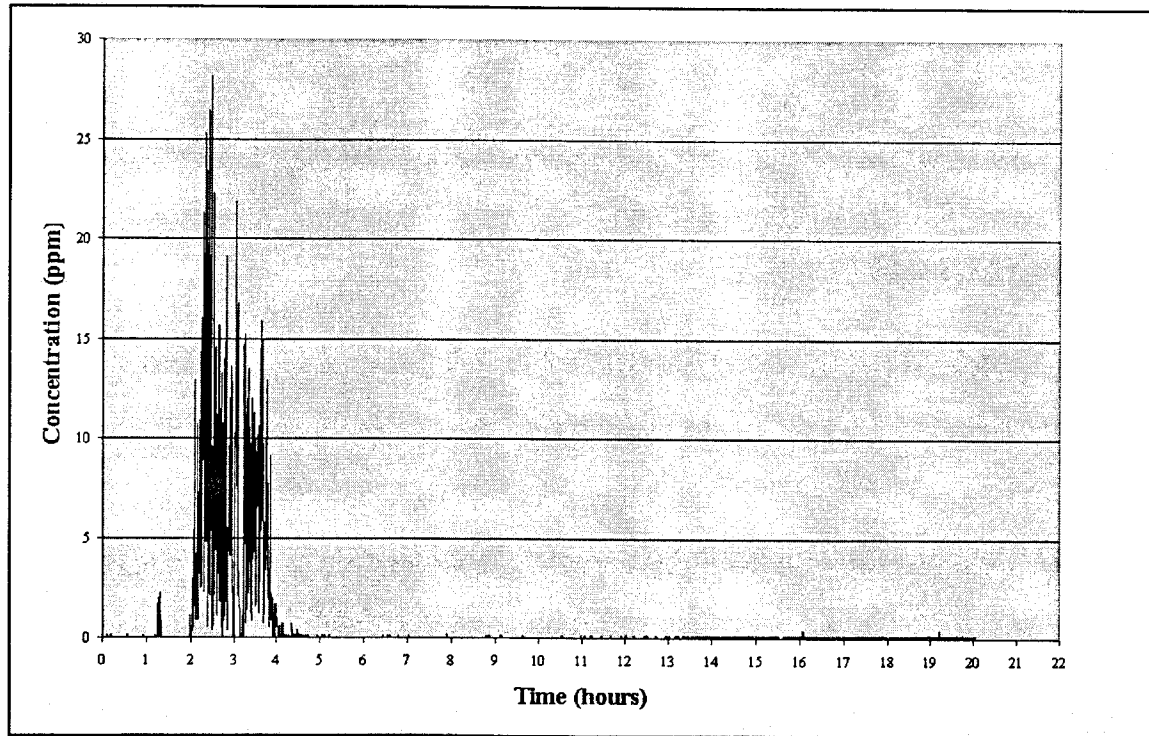


Figure 5.3-1. Test 1 CO Concentration vs Time

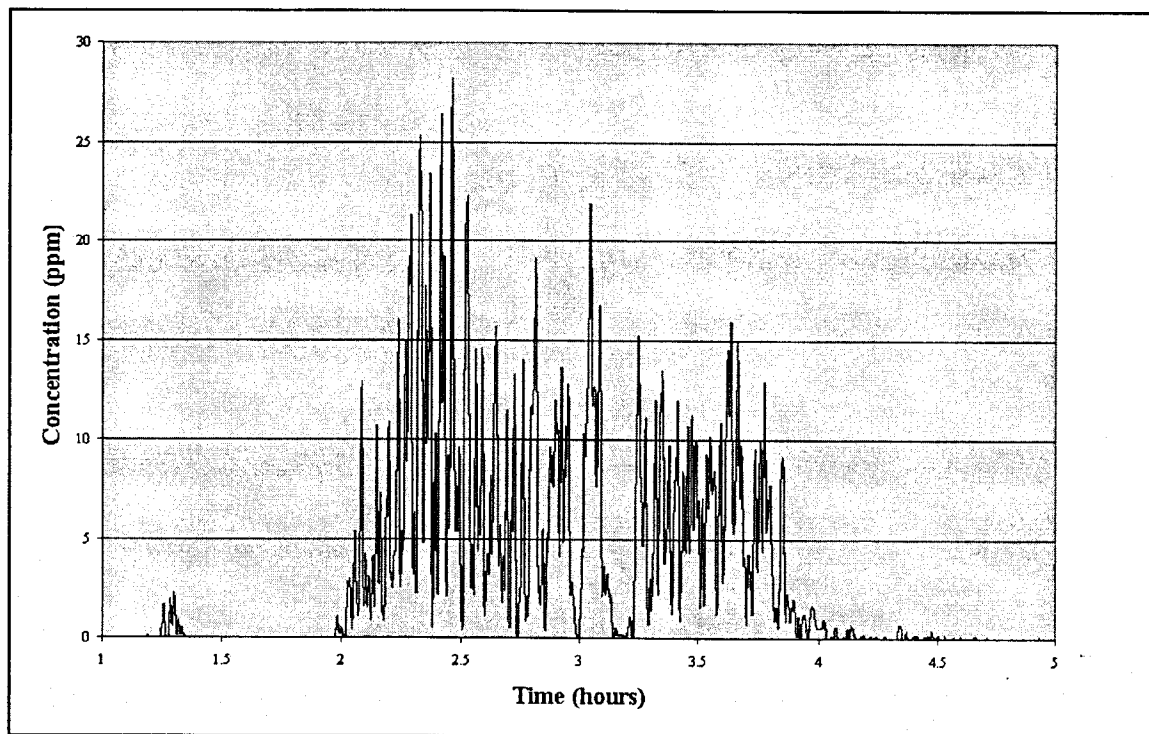


Figure 5.3-2. Test 1 CO Concentration vs Time for 1 to 5 hours

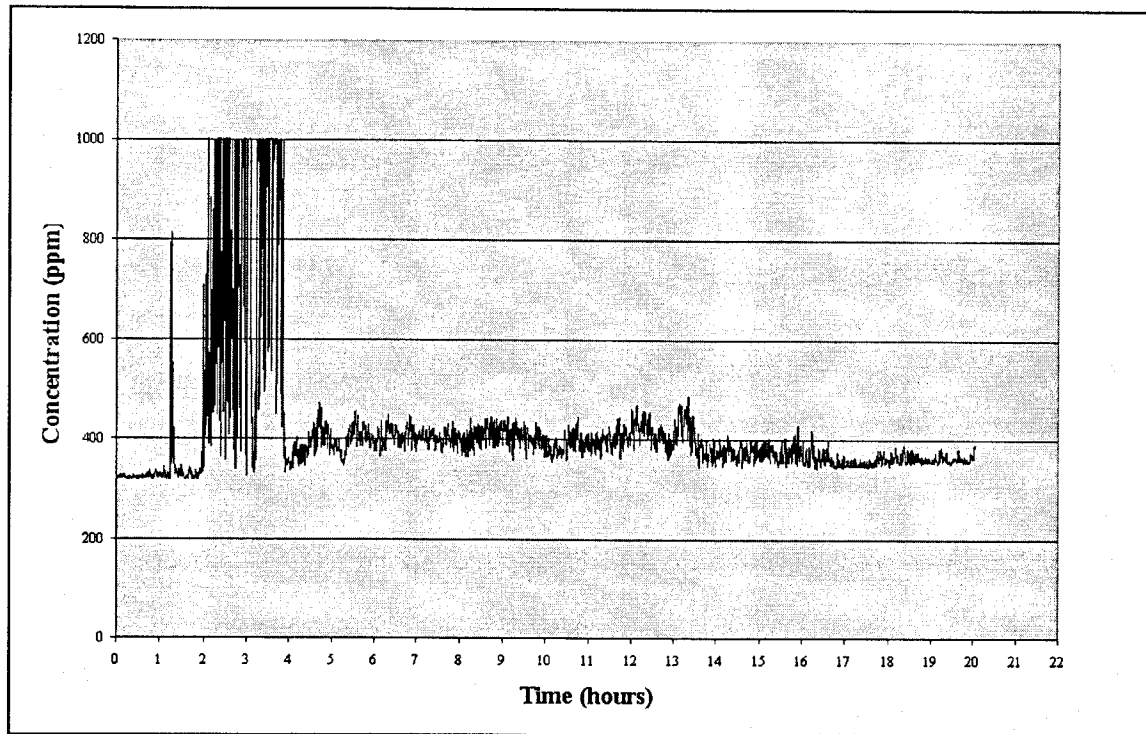


Figure 5.3-3. Test 1 CO₂ Concentration vs Time

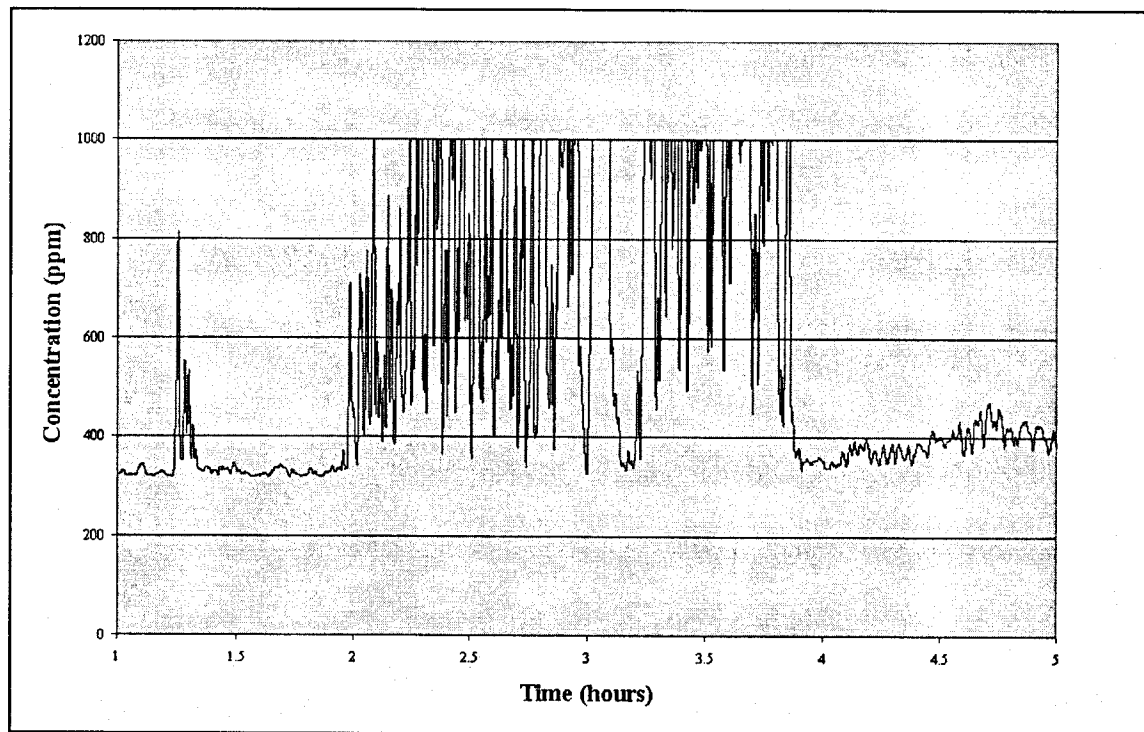


Figure 5.3-4. Test 1 CO₂ Concentration vs Time for 1 to 5 hours

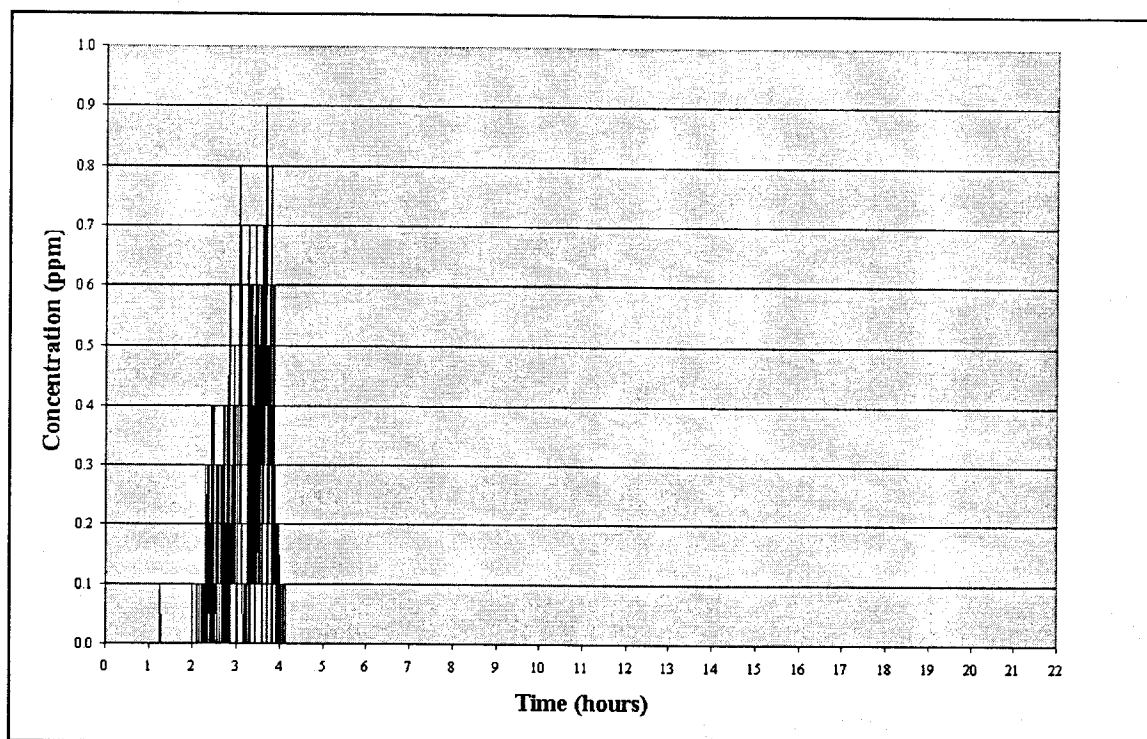


Figure 5.3-5. Test 1 NO_x Concentration vs Time

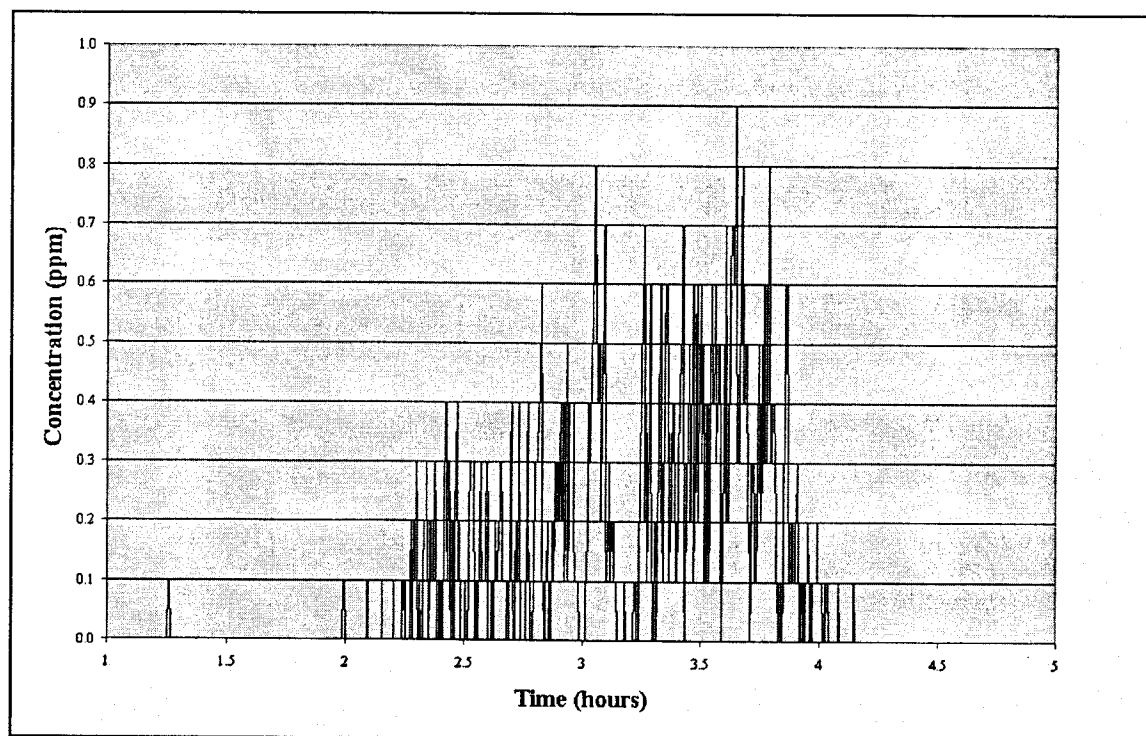


Figure 5.3-6. Test 1 NO_x Concentration vs Time for 1 to 5 hours

FINAL

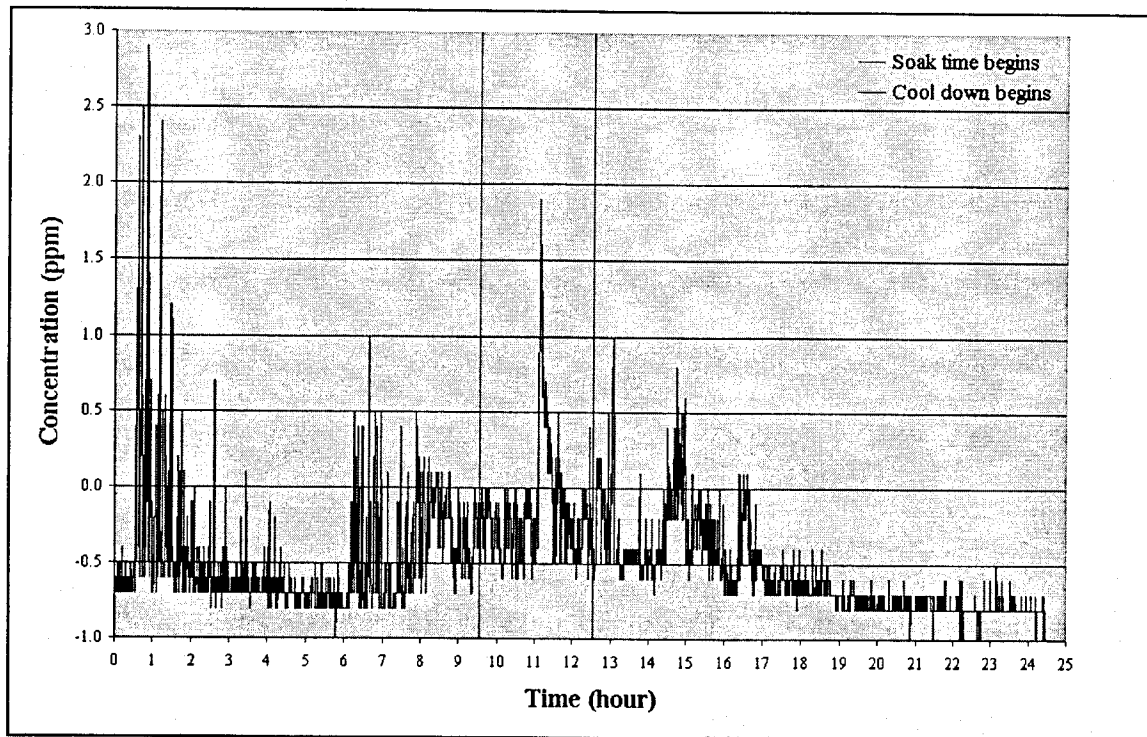


Figure 5.3-7. Test 2 CO Concentration vs Time

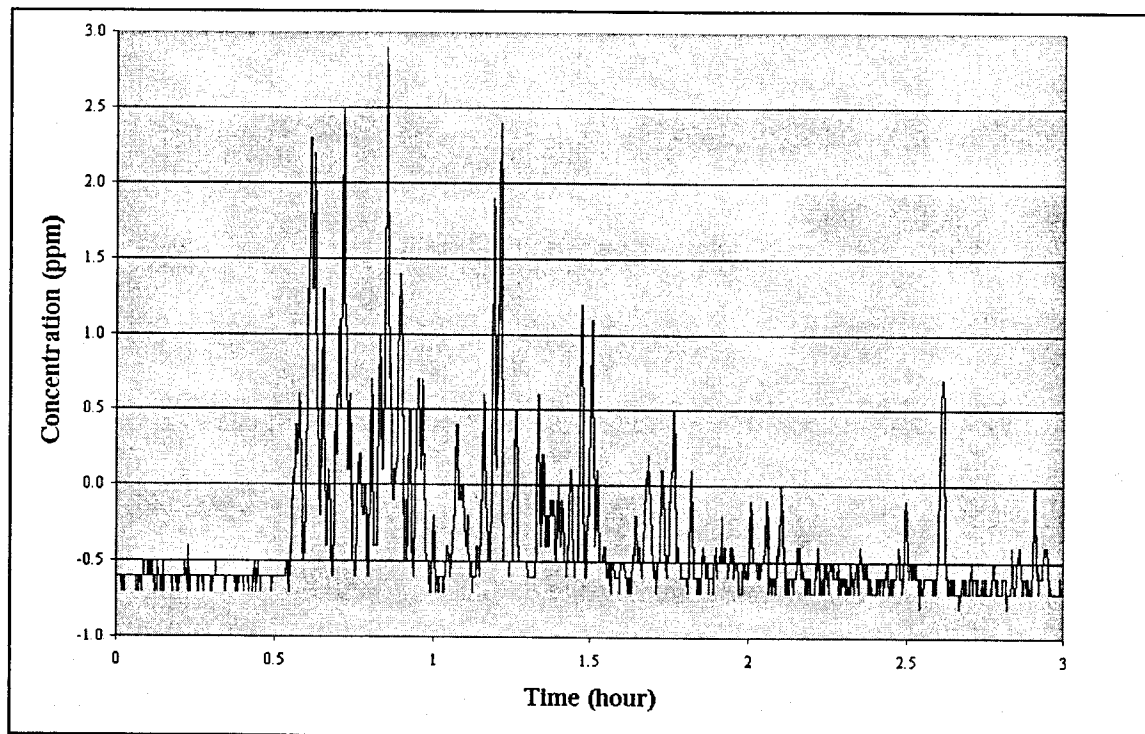


Figure 5.3-8. Test 2 CO Concentration vs Time for 0 to 3 hours

FINAL

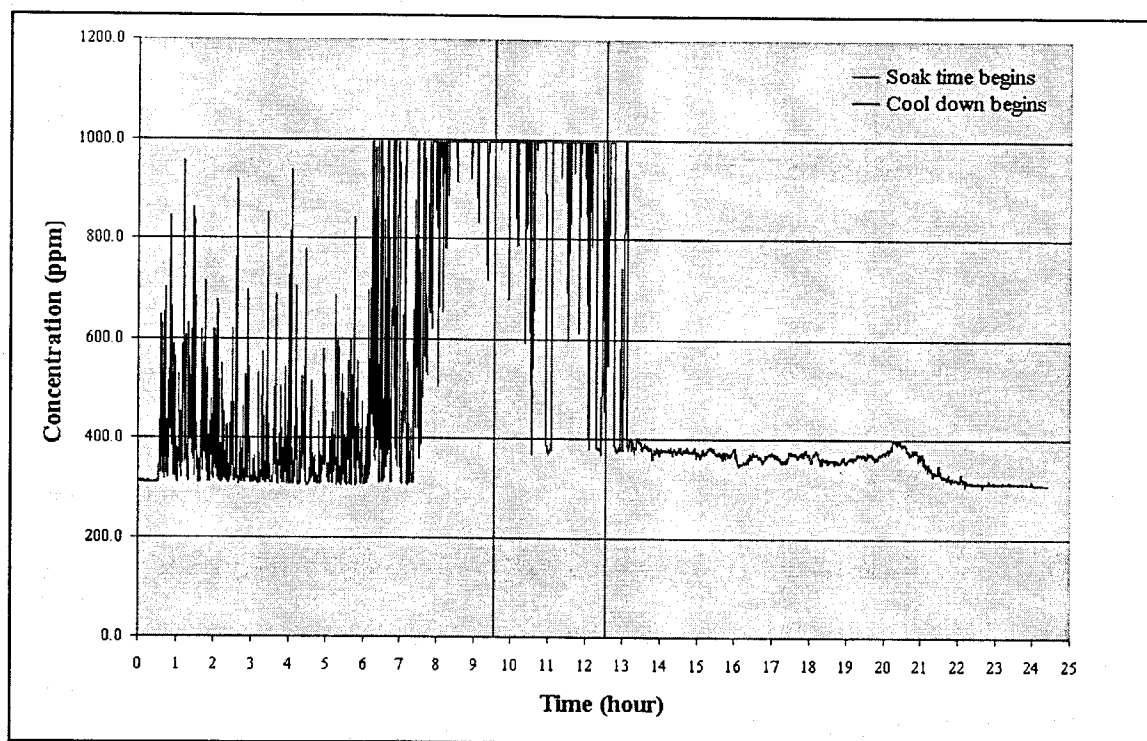


Figure 5.3-9 Test 2 CO₂ (1-1000 ppm) Concentration vs Time

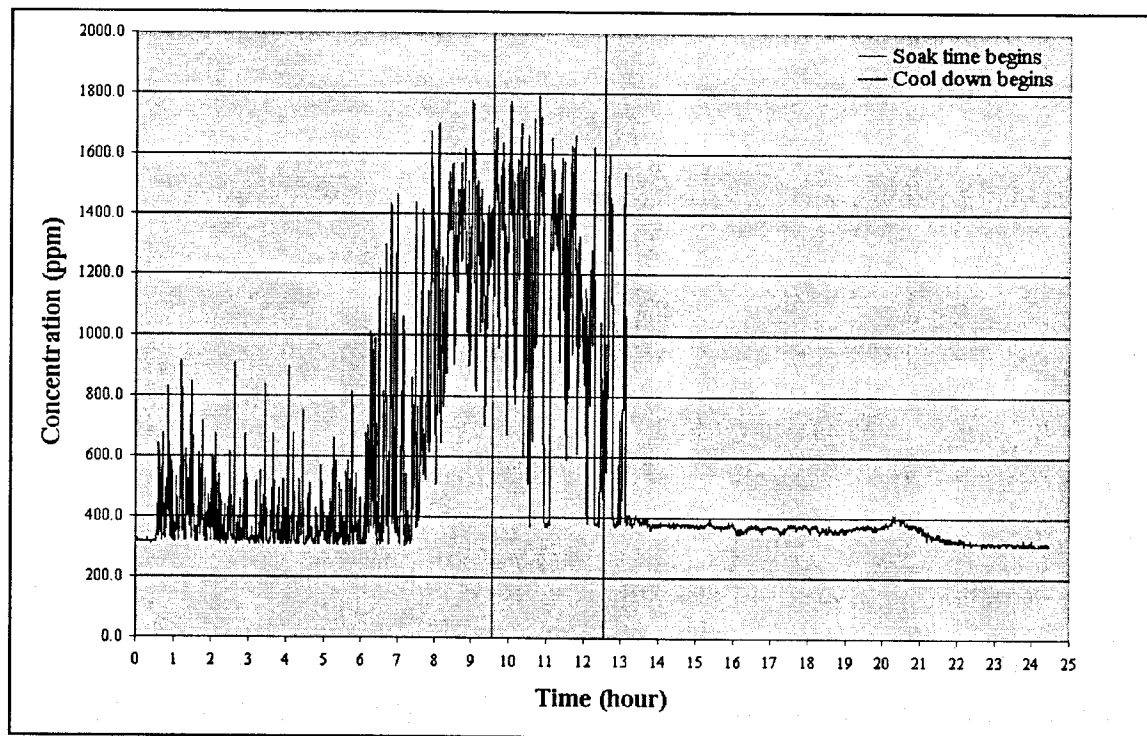


Figure 5.3-10 Test 2 CO₂ (1-5000 ppm) Concentration vs Time

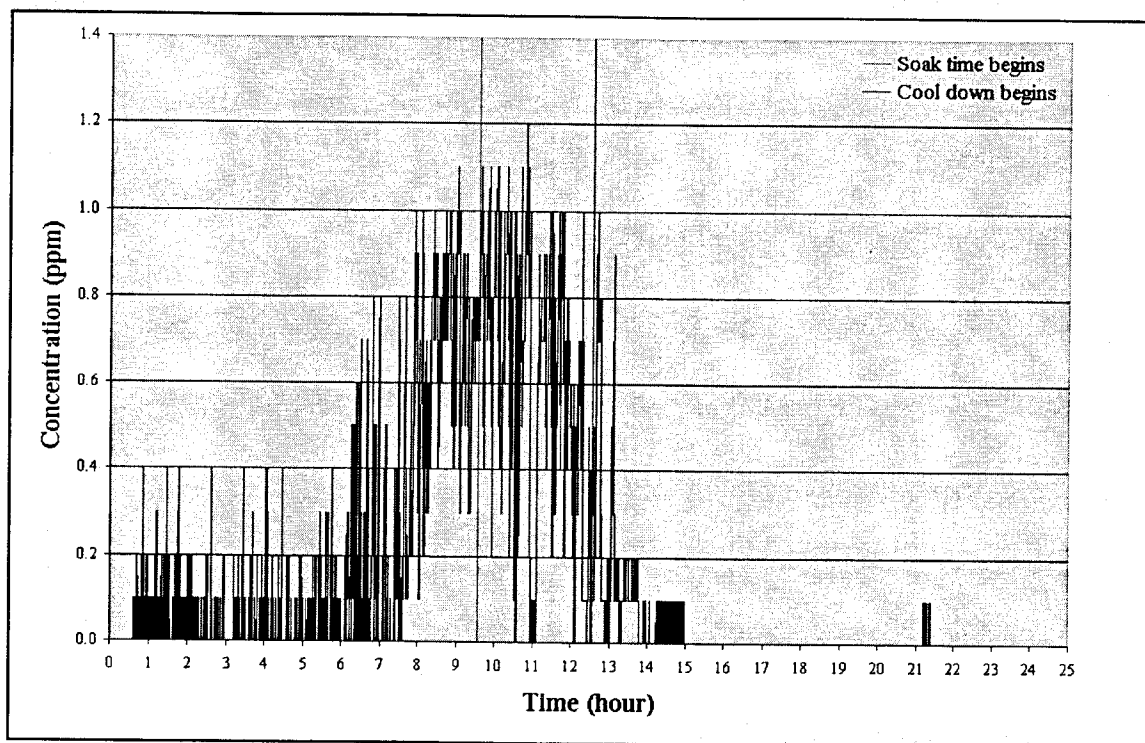


Figure 5.3-11. Test 2 NO_x Concentration vs Time

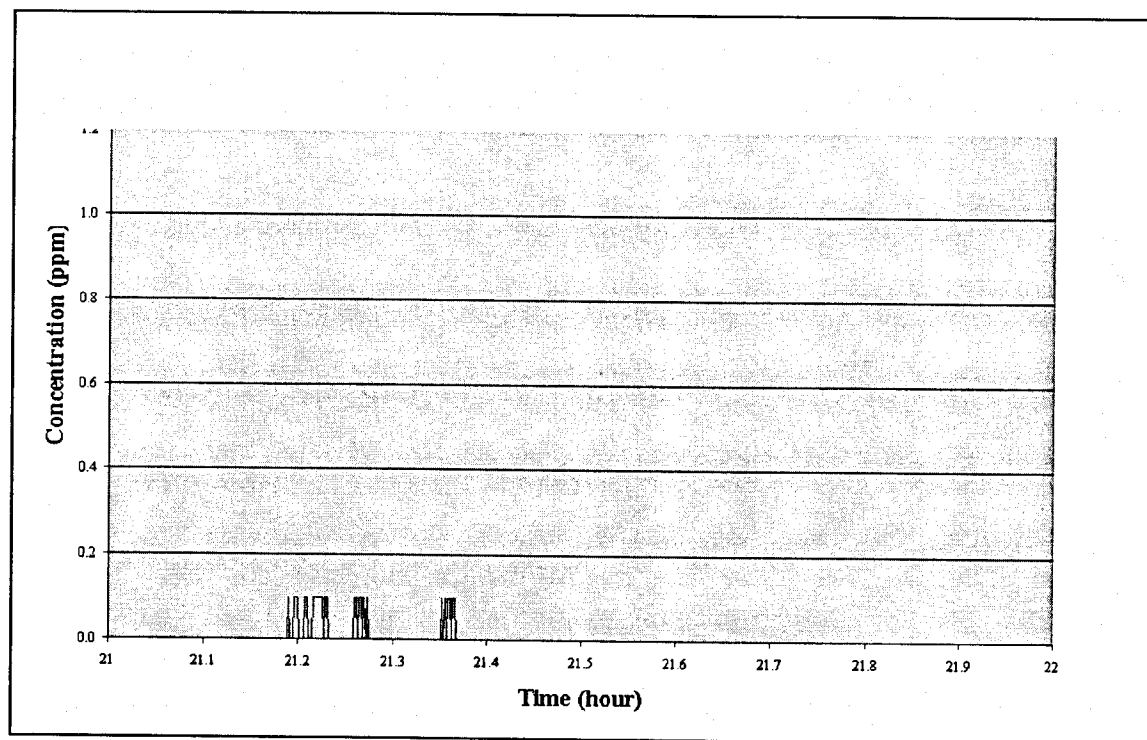


Figure 5.3-12. Test 2 NO_x Concentration vs Time for 21 to 21.5 hours

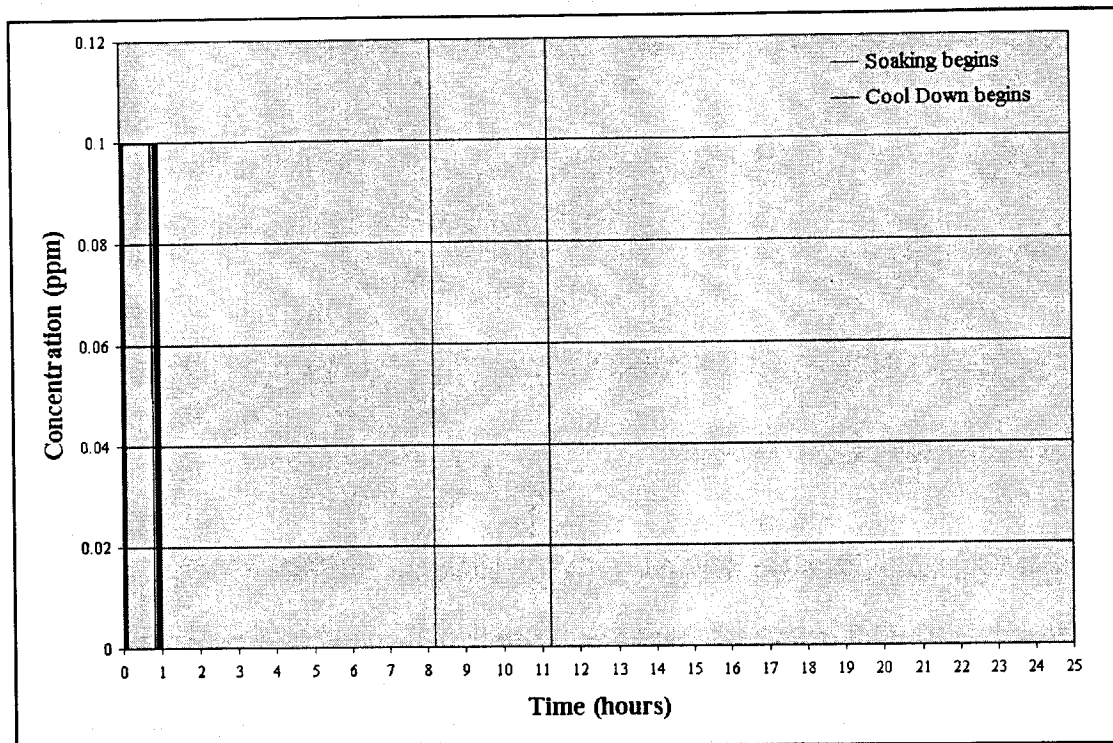


Figure 5.3-13. Test 6 SO₂ Concentration vs Time

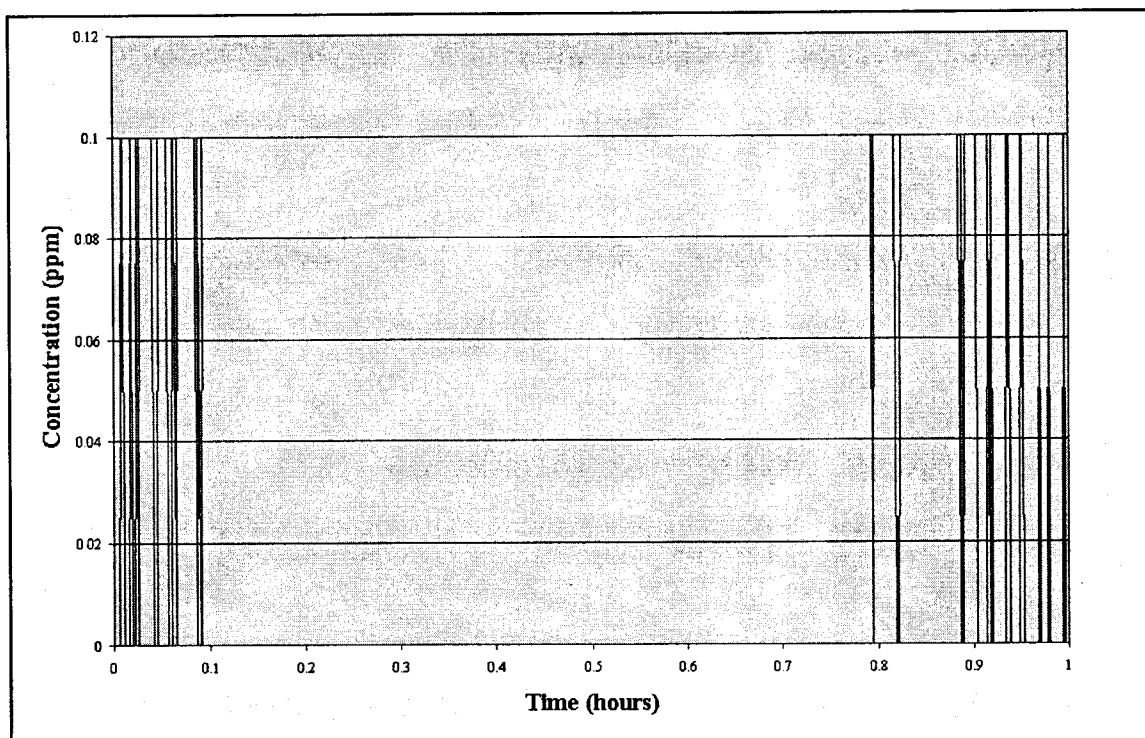


Figure 5.3-14. Test 6 SO₂ Concentration vs Time for 0 to 1 hour

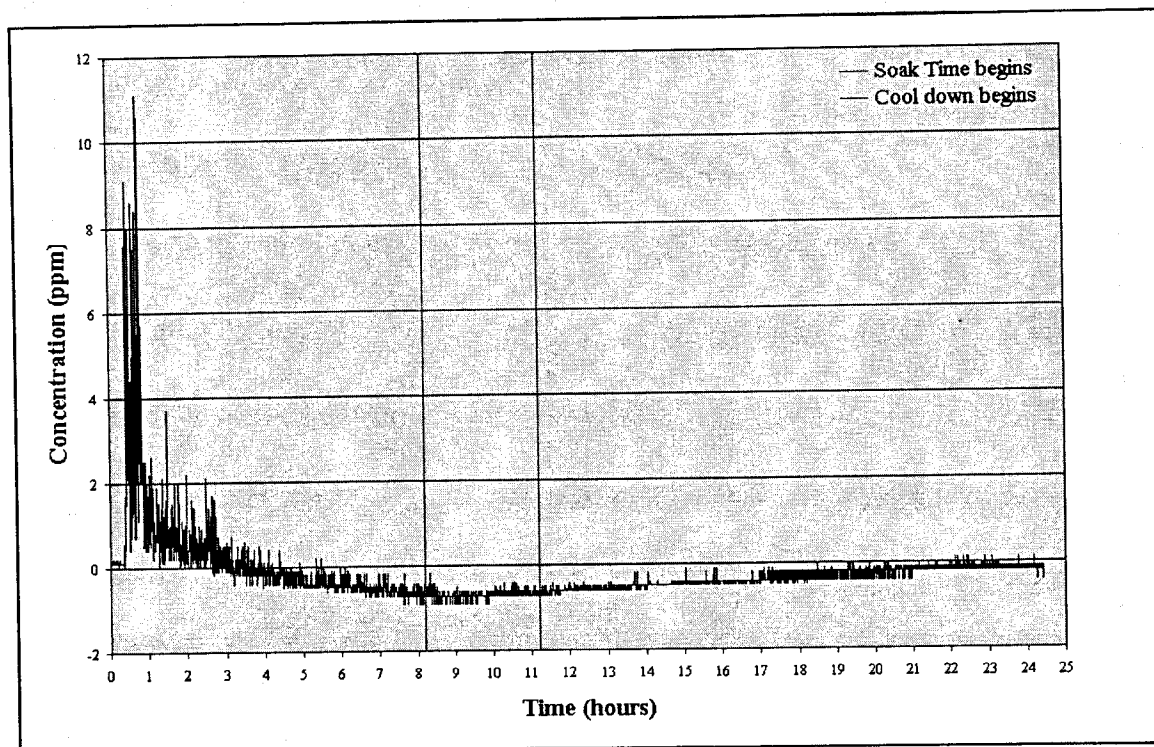


Figure 5.3-15. Test 6 CO Concentration vs Time on 16 October 2001

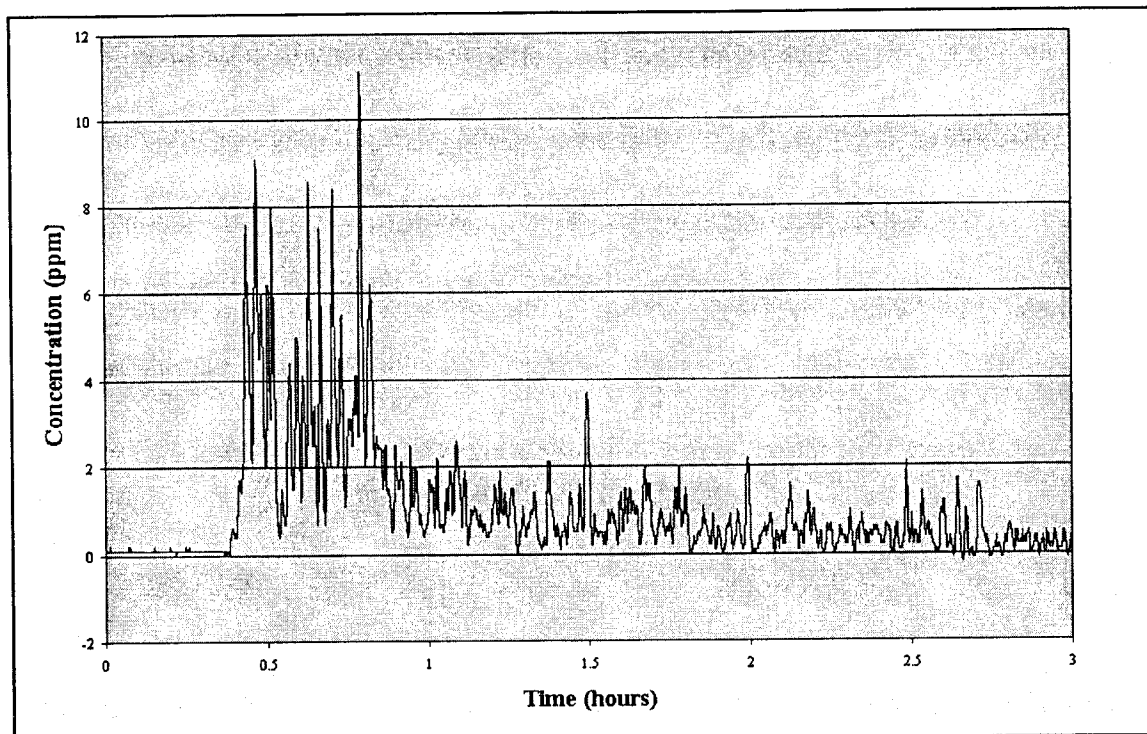


Figure 5.3-16. Test 6 CO Concentration vs Time for 0 to 3 hours

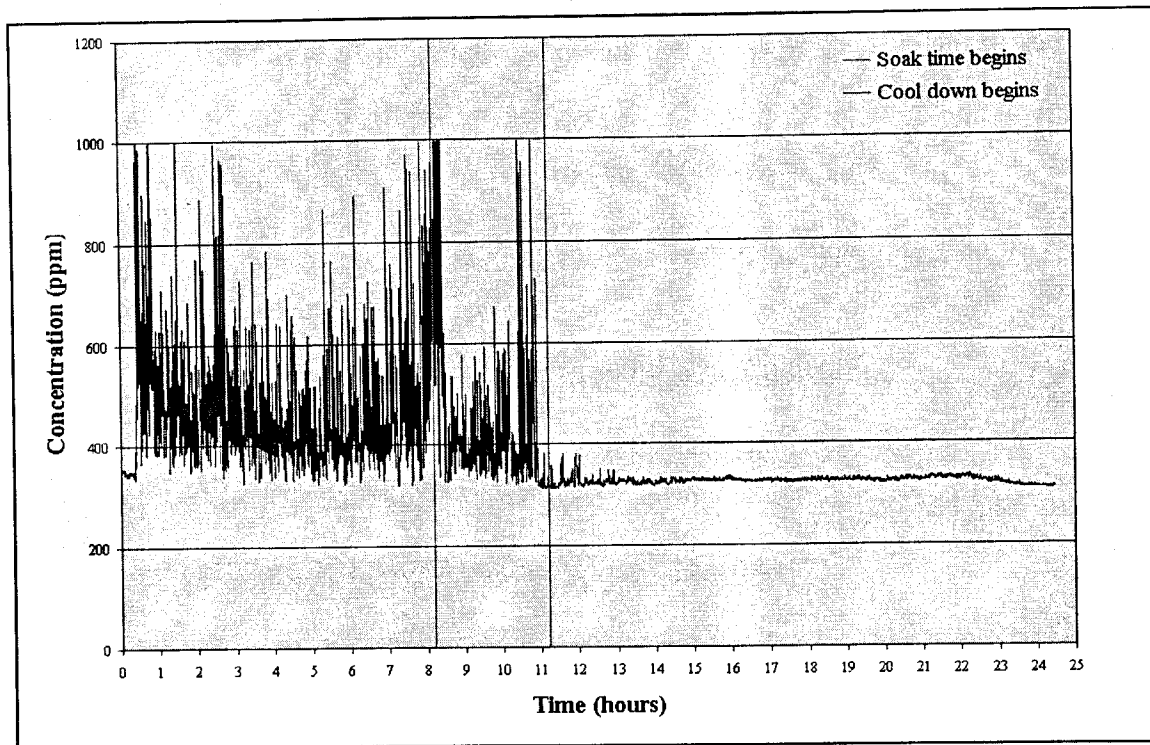


Figure 5.3-17. Test 6 CO₂ (0-1000ppm) Concentration vs Time

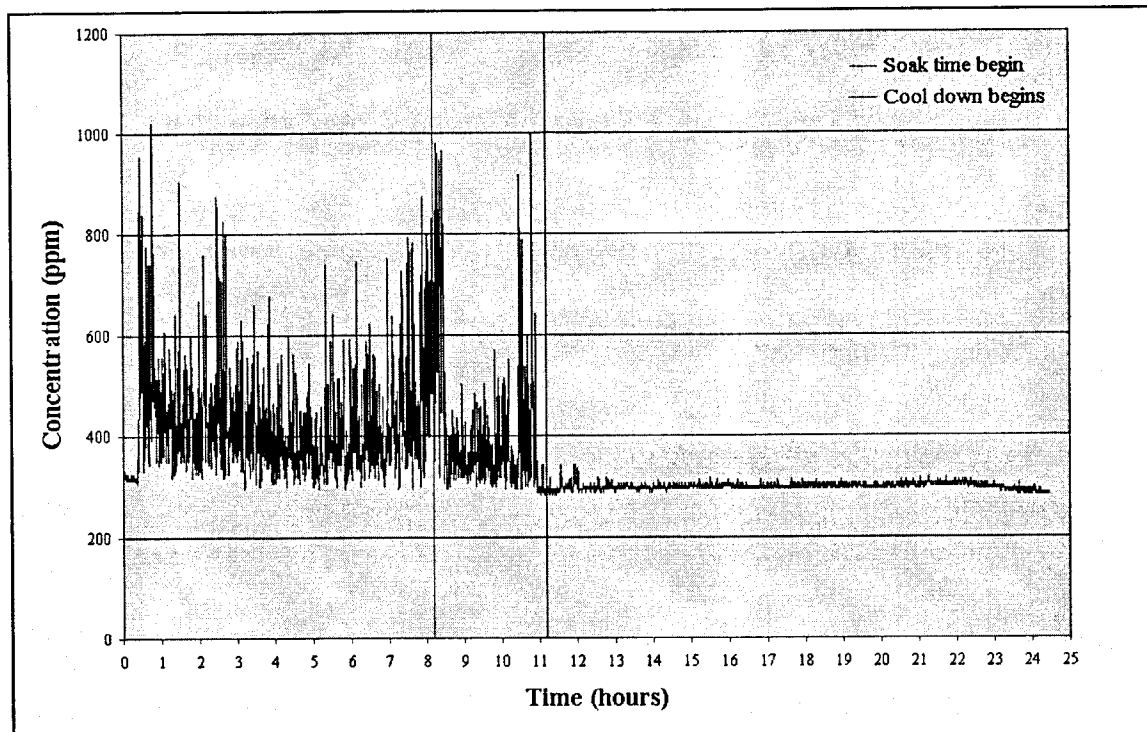


Figure 5.3-18. Test 6 CO₂ (0-5000ppm) Concentration vs Time

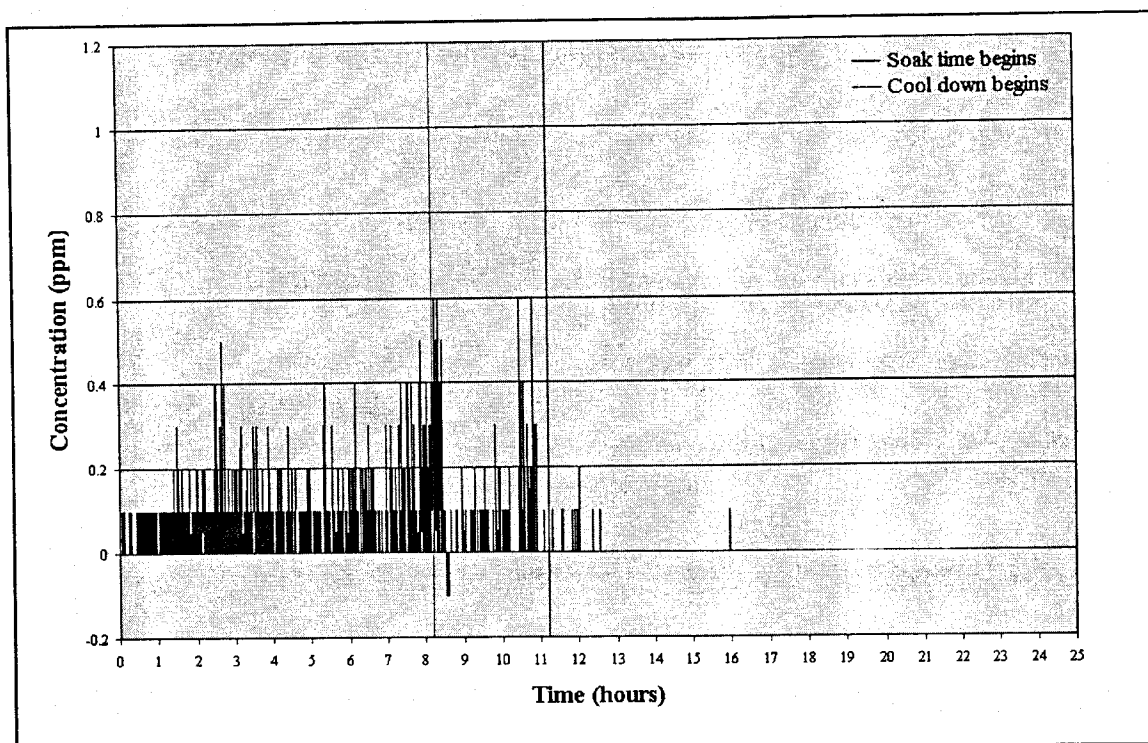


Figure 5.3-19. Test 6 NO_x Concentration vs Time

Volatile Organic Compound. The majority of VOCs were not quantifiable above the analytical detection limit with the exception of those listed in Table 5.3-2 below. Of those that were detected, none of them were close to the 1/100 Threshold Limit Value. A list of all VOCs that were monitored for are shown in Tables EX 1 through EX 5 of CHPPM Report²⁷ in Appendix B of this report.

FINAL

Table 5.3-2. Volatile Organic Compound Concentrations Summary

Target Analyte	CAS Number	Concentration (ppb)				1/100 of TLV ^a (ppb)
		Location near Pile				
		Front	Left	Right	Top	
Background	10 Aug 01					
Pentane	109-66-0	7.0	<1.0	<1.0	<1.0	6,000
Freon 113	76-13-1	<1.0	4.0	<1.0	<1.0	10,000
Acetone	67-64-1	7.0	8.0	9.0	6.0	5,000
Carbon Disulfide	75-15-0	3.0	<1.0	<1.0	<1.0	100
Acetonitrile	75-05-8	<1.0	4.0	<1.0	<1.0	400
Methylene Chloride	75-09-2	<1.0	9.0	<1.0	<1.0	500
Hexane	110-54-3	7.0	<1.0	<1.0	<1.0	5,000
2-Butanone	78-93-3	8.0	<1.0	<1.0	<1.0	2,000
Isooctane	540-84-1	14.0	<1.0	<1.0	<1.0	N/A ^d
Heptane	142-82-5	2.0	<1.0	<1.0	<1.0	4,000
Toluene	108-88-3	3.0	<1.0	<1.0	<1.0	500
m/p-Xylene	1330-20-7	2.0	<1.0	<1.0	<1.0	1,000
Butane, 2-methyl- ^b	78-78-4	23.0	ND ^c	ND ^c	ND ^c	N/A ^d
Cyclobutane, ethyl- ^b	4806-61-5	5.0	ND ^c	ND ^c	ND ^c	N/A ^d
Hexane, 2-methyl- ^b	591-76-4	4.0	ND ^c	ND ^c	ND ^c	N/A ^d
Ethanol	64-17-5	ND ^c	ND ^c	2.0	5.0	10,000

^a TWA taken from: Threshold Limit Values for Chemical Substances and Physical Agents, ACGIH, 2000.

^b Estimated concentrations assuming identical response factor to that of the internal standard with retention time closest to the tentatively identified compound (TIC).

^c ND: Not Detected.

^d N/A: No TLV data available.

Note: The "<" indicates that the compound was not quantified above the analytical detection limit for that sample.

FINAL

Table 5.3-2. Volatile Organic Compound Concentrations Summary (Cont'd)

Target Analyte	CAS Number	Concentration (ppb)				1/100 of TLV ^a (ppb)
		Location near Pile				
		Front	Left	Right	Top	
Test 1	16 Aug 01					
Propene	115-07-1	<1.0	<1.0	<1.0	3.0	N/A ^d
Acetone	67-64-1	9.0	10.0	10.0	7.0	5,000
Ethanol	64-17-5	ND ^c	8.0	59.0	2.0	10,000
Acetaldehyde ^b	75-07-0	1.0	2.0	2.0	1.0	N/A ^d
1,2-Pentadiene ^b	591-95-7	1.0	ND ^c	ND ^c	ND ^c	N/A ^d
1,3-Butadiene, 2-methyl- ^b	926-54-5	ND ^c	2.0	ND ^c	2.0	N/A ^d
Test 2	5 Sept 01					
Acetone	67-64-1	6.0	5.0	7.0	4.0	5,000
Ethanol	64-17-5	2.0	7.0	17.0	5.0	10,000
Acetaldehyde ^b	75-07-0	ND ^c	1.0	2.0	ND ^c	N/A ^d
Test 6	16 Oct 01					
Propene	115-07-1	2.0	<1.0	<1.0	1.0	N/A ^d
Acetone	67-64-1	6.0	7.0	8.0	5.0	5,000
tert-Butyl Alcohol	75-65-1	<1.0	<1.0	<1.0	10.0	1,000
Benzene	71-43-2	<1.0	1.0	<1.0	<1.0	5
Ethanol	64-17-5	2.0	8.0	20.0	12.0	10,000

^a TWA taken from: Threshold Limit Values for Chemical Substances and Physical Agents, ACGIH, 2000.

^b Estimated concentrations assuming identical response factor to that of the internal standard with retention time closest to the tentatively identified compound (TIC).

^c ND: Not Detected.

^d N/A: No TLV data available.

Note: The "<" indicates that the compound was not quantified above the analytical detection limit for that sample.

FINAL

Polycyclic Aromatic Hydrocarbons. The majority of the polycyclic aromatic hydrocarbons (PAHs) were quantifiable above the analytical detection limit. Of those that were detected, none of them were close to the 1/100 of the Threshold Limit Value. Table 5.3-3 below gives a summary of those analytes that were detected. A list of all PAHs that were monitored for are shown in Tables EX 6 through EX 10 of CHPPM Report²⁷ in Appendix B of this report.

Table 5.3-3. Polycyclic Aromatic Hydrocarbons Concentrations Summary

Target Analyte	CAS Number	Concentration (µg/m³)				1/100 of TLV ^a (µg/m³)
		Location near Pile				
		Front	Left	Right	Top	
Background	10 Aug 01					
Naphthalene	91-20-3	0.03139	0.04932	0.04859	0.04538	100
Acenaphthylene	208-96-8	0.00020	0.00023	0.00019	0.00018	2 ^b
Acenaphthene	83-32-9	0.00615	0.00705	0.00884	0.00864	2 ^b
Fluorene	86-73-7	0.00677	0.00007	0.00773	0.00918	2 ^b
Phenanthrene	85-01-8	0.00923	0.00976	0.00994	0.01459	2 ^b
Anthracene	120-12-7	0.00021	0.00032	0.00020	0.00012	2 ^b
Fluoranthene	206-44-0	0.00111	0.00114	0.00105	0.00157	2 ^b
Pyrene	129-00-0	0.00074	0.00065	0.00061	0.00157	2 ^b
Benzo[a]anthracene	56-55-3	0.00006	0.00007	<0.00006	0.00006	2 ^b
Chrysene	218-01-9	0.00017	0.00020	0.00007	0.00022	2 ^b
TEST 1	16 Aug 01					
Naphthalene	91-20-3	0.01928	0.02979	0.03010	0.05395	100
Acenaphthylene	208-96-8	0.00031	<0.00006	0.00018	0.00926	2 ^b
Acenaphthene	83-32-9	0.00374	0.00436	0.00436	0.00480	2 ^b
Fluorene	86-73-7	0.00442	0.00303	0.00311	0.00599	2 ^b
Phenanthrene	85-01-8	0.01134	0.00479	0.00306	0.01580	2 ^b
Anthracene	120-12-7	0.00029	0.00011	0.00015	0.00049	2 ^b
Fluoranthene	206-44-0	0.00119	0.00080	0.00067	0.00523	2 ^b
Pyrene	129-00-0	0.00057	0.00046	0.00041	0.00218	2 ^b
Benzo[a]anthracene	56-55-3	0.00008	<0.00006	<0.00006	0.00049	2 ^b

^a TWA taken from: Threshold Limit Values for Chemical Substances and Physical Agents, ACGIH, 2000.

^b The only TWA for these PAHs is expressed in Particulate Polycyclic Aromatic Hydrocarbons (PPAH).

Note: The "<" indicates that the compound was not quantified above the analytical detection limit for that sample.

Table 5.3-3. Polycyclic Aromatic Hydrocarbons Concentrations Summary (Cont'd)

Target Analyte	CAS Number	Concentration (µg/m³)				1/100 of TLV ^a (µg/m³)
		Location near Pile				
		Front	Left	Right	Top	
Chrysene	218-01-9	0.00113	0.00069	0.00025	0.00926	2 ^b
Benzo[b]fluoranthene	205-99-2	0.00006	0.00006	<0.00006	0.00026	2 ^b
Benzo[k]fluoranthene	207-08-9	<0.00006	<0.00006	<0.00006	0.00015	2 ^b
Benzo[e]pyrene	192-97-2	0.00023	0.00007	<0.00006	0.00213	2 ^b
Benzo[a]pyrene	50-32-8	0.00013	0.00010	0.00006	0.00029	2 ^b
Indeno[1,2,3-cd]pyrene	193-39-5	<0.00006	<0.00006	<0.00006	0.00009	2 ^b
Benzo[g,h,i]perylene	191-24-2	<0.00006	<0.00006	<0.00006	0.00010	2 ^b
TEST 2	5 Sept 01					
Naphthalene	91-20-3	0.05039	0.05822	0.04899	0.05961	100
Acenaphthylene	208-96-8	0.00055	0.00053	0.00047	0.00152	2 ^b
Acenaphthene	83-32-9	0.00203	0.00217	0.00151	0.00076	2 ^b
Fluorene	86-73-7	0.00460	0.00503	0.00386	0.00439	2 ^b
Phenanthrene	85-01-8	0.00767	0.00741	0.00573	0.00705	2 ^b
Anthracene	120-12-7	0.00016	0.00017	0.00014	0.00028	2 ^b
Fluoranthene	206-44-0	0.00060	0.00074	0.00089	0.00081	2 ^b
Pyrene	129-00-0	0.00066	0.00058	0.00049	0.00087	2 ^b
Benzo[a]anthracene	56-55-3	<0.00006	<0.00006	0.00006	0.00007	2 ^b
Chrysene	218-01-9	0.00008	0.00017	0.00015	0.00018	2 ^b
Benzo[b]fluoranthene	205-99-2	0.00007	<0.00006	0.00010	0.00008	2 ^b
Benzo[k]fluoranthene	207-08-9	<0.00006	<0.00006	0.00006	0.00007	2 ^b
Benzo[e]pyrene	192-97-2	0.00008	0.00016	0.00052	0.00047	2 ^b
Benzo[g,h,i]perylene	191-24-2	<0.00006	<0.00006	0.00006	0.00009	2 ^b

^a TWA taken from: Threshold Limit Values for Chemical Substances and Physical Agents, ACGIH, 2000.

^b The only TWA for these PAHs is expressed in Particulate Polycyclic Aromatic Hydrocarbons (PPAH),

Note: The "<" indicates that the compound was not quantified above the analytical detection limit for that sample.

Table 5.3-3. Polycyclic Aromatic Hydrocarbons Concentrations Summary (Cont'd)

Target Analyte	CAS Number	Concentration (µg/m³)				1/100 of TLV ^a (µg/m³)
		Location near Pile				
		Front	Left	Right	Top	
TEST 6	16 Oct 01					
Naphthalene	91-20-3	0.08204	0.05593	0.04012	0.11583	100
Acenaphthylene	208-96-8	0.00100	0.00047	0.00038	0.00258	2 ^b
Acenaphthene	83-32-9	0.00199	0.00168	0.00116	0.00121	2 ^b
Fluorene	86-73-7	0.00645	0.00447	0.00296	0.01106	2 ^b
Phenanthrene	85-01-8	0.02813	0.02187	0.00845	0.05160	2 ^b
Anthracene	120-12-7	0.00164	0.00132	0.00034	0.00253	2 ^b
Fluoranthene	206-44-0	0.00762	0.00712	0.00195	0.01474	2 ^b
Pyrene	129-00-0	0.00703	0.00661	0.00195	0.01474	2 ^b
Benzo[a]anthracene	56-55-3	0.00135	0.00076	<0.00026	0.00232	2 ^b
Chrysene	218-01-9	0.00240	0.00137	0.00058	0.00295	2 ^b
Benzo[b]fluoranthene	205-99-2	0.00234	0.00097	0.00049	0.00200	2 ^b
Benzo[k]fluoranthene	207-08-9	0.00129	0.00051	0.00027	0.00074	2 ^b
Benzo[e]pyrene	192-97-2	0.00176	0.00142	0.00095	0.00305	2 ^b
Benzo[a]pyrene	50-32-8	0.00035	0.00026	<0.00026	0.00074	2 ^b
Indeno[1,2,3-cd]pyrene	193-39-5	0.00100	0.00035	0.00022	0.00063	2 ^b
Dibenz[a,h]anthracene	53-7-3	0.00105	0.00018	0.00013	0.00048	2 ^b
Benzo[g,h,i]perylene	191-24-2	0.00146	0.00061	0.00045	0.00179	2 ^b

^a TWA taken from: Threshold Limit Values for Chemical Substances and Physical Agents, ACGIH, 2000.

^b The only TWA for these PAHs is expressed in Particulate Polycyclic Aromatic Hydrocarbons (PPAH),

Note: The "<" indicates that the compound was not quantified above the analytical detection limit for that sample.

FINAL

Semi-Volatile Organic Compound. The majority of the SVOCs analytes were not quantified above the detection limit. Among those that were found to be above the detection limit the common emissions were Phenol, Benzaldehyde, and Bis(2-Ethylhexyl)phthalate. None of the detected emissions were over the 1/100 of the TLV value. Table 5.3-4 gives a summary of the analytes that were detected. A list all SVOCs that were analyzed are shown in EX 21 through EX 25 of the CHPPM Report²⁷ in Appendix B of this report.

Table 5.3-4. Semi-Volatile Organic Compound Concentrations Summary

Target Analyte	CAS Number	Concentration (µg/m³)				1/100 of TLV ^a (µg/m³)
		Location near Pile				
		Front	Left	Right	Top	
BACKGROUND	10 Aug 01					
Di-n-butylphthalate	84-74-2	0.08617	0.05961	<0.05522	NR ^d	50
bis(2-Ethylhexyl)phthalate	117-81-7	<0.06155	0.10839	0.05522	NR ^d	N/A ^b
TEST 1	16 Aug 01					
Phenol	108-95-2	0.15313	0.06384	<0.05189	0.76298	N/A ^b
Hexachloroethane	67-72-1	<0.056715	<0.05320	<0.05189	0.40874	10
2-Nitrophenol	88-75-5	<0.056715	<0.05320	<0.05189	0.08720	N/A ^b
Di-n-butylphthalate	84-74-2	<0.056715	<0.05320	<0.05189	0.06540	50
bis(2-Ethylhexyl)phthalate	117-81-7	0.21552	0.33516	0.20239	0.19075	N/A ^b
Bicyclo[4.2.0]octa-1,3,5-triene ^c	000694-87-1	0.15313	0.15428	0.15568	<0.054499	N/A ^b
Benzaldehyde ^c	000100-52-7	0.13612	0.07980	0.07265	<0.054499	N/A ^b
Limonene ^c	000138-86-3	<0.056715	0.09576	<0.05189	<0.054499	N/A ^b
1,4-Benzenedicarboxaldehyde ^c	000623-27-8	<0.056715	0.10108	<0.05189	<0.054499	N/A ^b

^a TWA taken from: Threshold Limit Values for Chemical Substances and Physical Agents, ACGIH, 2000.

^b N/A: No TLV data available.

^c Estimated concentrations assuming identical response factor to that of the internal standard with retention time closest to the tentatively identified compound (TIC).

^d NR: No results reported. Sample was compromised during the extraction concentration step.

Note: The "<" indicates that the compound was not quantified above the analytical detection limit for that sample. Bold type indicates the highest concentration of each analyte.

Table 5.3-4. Semi-Volatile Organic Compound Concentrations Summary (Cont'd)

Target Analyte	CAS Number	Concentration (µg/m³)				1/100 of TLV ^a (µg/m³)
		Location near Pile				
		Front	Left	Right	Top	
Ethanone, 1-(4-ethylphenyl)- ^c	000937-30-4	0.17015	<0.05320	<0.05189	<0.054499	N/A ^b
n-Hexadecanoic acid ^c	000057-10-3	0.33462	<0.05320	<0.05189	0.59949	N/A ^b
1-Butanol,3-methyl-,acetate ^c	000123-92-2	1.41788	<0.05320	<0.05189	<0.054499	N/A ^b
Ethanone, 1-(3,4-dimethylphenyl)- ^c	003637-01-2	0.21552	<0.05320	<0.05189	<0.054499	N/A ^b
Phthalic anhydride ^c	000085-44-9	0.12477	0.18088	<0.05189	1.90746	N/A ^b
1 H-Isoindole-1,3(2H)-dione ^c	000085-41-6	0.27223	0.07980	<0.05189	0.21800	N/A ^b
3,4-DNT (Benzene, 4-methyl-1,2-)- ^c	000610-39-9	0.15880	<0.05320	<0.05189	<0.054499	N/A ^b
Tetracosane ^c	000646-31-1	0.10776	<0.05320	<0.05189	0.87198	N/A ^b
Octicizer ^c	001241-94-7	0.14179	0.08512	<0.05189	0.32699	N/A ^b
Hexacosane ^c	000630-01-3	0.11343	<0.05320	<0.05189	1.47147	N/A ^b
Nonacosane ^c	000630-03-5	0.12477	<0.05320	<0.05189	0.40874	N/A ^b
Benzoic Acid ^c	000065-85-0	0.10776	0.10108	<0.05189	<0.054499	N/A ^b
Naphthalene,2,3,6-trichloro- ^c	055720-40-6	<0.056715	<0.05320	<0.05189	0.44144	N/A ^b
Octadecanoic acid ^c	000057-11-4	<0.056715	<0.05320	<0.05189	0.32699	N/A ^b
Docosane ^c	000629-97-0	<0.056715	<0.05320	<0.05189	0.20710	N/A ^b
Phenol,4,4'-(1-methylethylidene)- ^c	000080-05-7	<0.056715	<0.05320	<0.05189	0.76298	N/A ^b
Tricosane ^c	000638-67-5	<0.056715	<0.05320	<0.05189	0.46324	N/A ^b
Pentacosane ^c	000629-99-2	<0.056715	<0.05320	<0.05189	1.36247	N/A ^b
Heptacosane ^c	000593-49-7	<0.056715	<0.05320	<0.05189	1.47147	N/A ^b

^a TWA taken from: Threshold Limit Values for Chemical Substances and Physical Agents, ACGIH, 2000.

^b N/A: No TLV data available.

^c Estimated concentrations assuming identical response factor to that of the internal standard with retention time closest to the tentatively identified compound (TIC).

Note: The "<" indicates that the compound was not quantified above the analytical detection limit for that sample. Bold type indicates the highest concentration of each analyte.

FINAL

Table 5.3-4. Semi-Volatile Organic Compound Concentrations Summary (Cont'd)

Target Analyte	CAS Number	Concentration (µg/m³)				1/100 of TLV ^a (µg/m³)
		Location near Pile				
		Front	Left	Right	Top	
Octacosane ^c	000630-02-4	<0.056715	<0.05320	<0.05189	1.08998	N/A ^b
Triacontane ^c	000638-68-6	<0.056715	<0.05320	<0.05189	0.21800	N/A ^b
TEST 2	5 Sept 01					
Phenol	108-95-2	<0.05477	0.06881	0.09381	0.59614	N/A ^b
bis(2-Ethylhexyl)phthalate	117-81-7	0.76683	7.93945	0.57330	0.59614	N/A ^b
Benzaldehyde ^c	000100-52-7	0.10955	0.11645	0.05212	0.34685	N/A ^b
Limonene ^c	000138-86-3	0.20266	0.16937	0.19805	<0.05419	N/A ^b
1,4-Benzene dicarboxaldehyde ^c	000623-27-8	0.14241	<0.05293	<0.05212	<0.05419	N/A ^b
n-Hexadecanoic acid ^c	000057-10-3	<0.05477	0.11645	<0.05212	0.70453	N/A ^b
Dodecane ^c	000112-40-3	0.09859	<0.05293	<0.05212	<0.05419	N/A ^b
Tetracosane ^c	000646-31-1	<0.05477	<0.05293	0.47428	0.65034	N/A ^b
Hexacosane ^c	000630-01-3	<0.05477	<0.05293	0.72966	0.92131	N/A ^b
Nonacosane ^c	000630-03-5	<0.05477	<0.05293	0.99025	<0.05419	N/A ^b
Benzoic Acid ^c	000065-85-0	<0.05477	<0.05293	<0.05212	0.29265	N/A ^b
Octadecanoic acid ^c	000057-11-4	<0.05477	<0.05293	<0.05212	0.54195	N/A ^b
Tricosane ^c	000638-67-5	<0.05477	<0.05293	0.27102	0.37936	N/A ^b
Pentacosane ^c	000629-99-2	<0.05477	<0.05293	0.62542	0.86711	N/A ^b
Heptacosane ^c	000593-49-7	<0.05477	<0.05293	0.78178	0.92131	N/A ^b
Octacosane ^c	000630-02-4	<0.05477	<0.05293	0.78178	0.81292	N/A ^b
Triacontane ^c	000638-68-6	<0.05477	<0.05293	0.62542	0.51485	N/A ^b
Toluene ^c	000108-88-3	0.12598	0.11645	<0.05212	<0.05419	N/A ^b
Benzene, 1-ethyl-2-methyl- ^c	000611-14-3	0.09311	<0.05293	<0.05212	<0.05419	N/A ^b
Hentriacontane ^c	000630-04-6	<0.05477	<0.05293	0.45864	0.39020	N/A ^b
Phenol, 2-ethyl- ^c	000090-00-6	<0.05477	<0.05293	<0.05212	0.33601	N/A ^b

^a TWA taken from: Threshold Limit Values for Chemical Substances and Physical Agents, ACGIH, 2000.

^b N/A: No TLV data available.

^c Estimated concentrations assuming identical response factor to that of the internal standard with retention time closest to the tentatively identified compound (TIC).

Note: The "<" indicates that the compound was not quantified above the analytical detection limit for that sample. Bold type indicates the highest concentration of each analyte.

Energetic And Explosive Compounds. The majority of energetic and explosive compounds were not quantifiable above the analytical detection limit, with the exception of 2,4,6 Trinitrotoluene (TNT) and RDX. Although these compounds were detected, they were significantly below the 1/100 Threshold Limit Values (TLV). Table 5.3-5 provides a summary of the detected energetic and explosive compounds. A list of all the energetic and explosive compounds concentrations that were monitored for are shown in Tables EX 11 through EX 15 of CHPPM Report²⁷ in Appendix B of this report.

Table 5.3-5. Energetic and Explosive Compound Concentrations Summary

Target Analyte	CAS Number	Concentration (µg/m³)				1/100 of
		Location near Pile				TLV ^a
		Front	Left	Right	Top	(µg/m³)
TEST 1	16 Aug 01					
2,4,6-Trinitrotoluene	118-96-7	0.02545	<0.01235	<0.01380	0.07646	1.0 ^b
RDX	121-82-4	0.06498	0.03345	<0.01380	0.11724	1.0
TEST 2	5 Sept 01					
2,4,6-Trinitrotoluene	118-96-7	<0.01253	<0.01217	0.02853	<0.01285	1.0 ^b
RDX	121-82-4	<0.01253	<0.01217	<0.01369	<0.01285	1.0
TEST 6	16 Oct 01					
2,4,6-Trinitrotoluene	118-96-7	0.16337	0.09908	0.05785	0.18450	1.0 ^b
RDX	121-82-4	0.04520	0.03389	<0.01388	0.05125	1.0

^a TWA taken from: Threshold Limit Values for Chemical Substances and Physical Agents, ACGIH, 2000.

^b The TWA for 2,4,6-Trinitrotoluene (TNT) [118-96-7] was assumed since it is the most conservative value.

Note: The "<" indicates that the compound was not quantified above the analytical detection limit for that sample. Bold type indicates the highest concentration of each analyte.

FINAL

Metals. The majority of the metal analytes were not quantified above the analytical detection limit. Those that were found in the samples were Aluminum, Barium, Cadmium, Calcium, Chromium, Copper, Iron, Lead, Magnesium, Mercury, Potassium, Sodium, and Zinc. Of those only the Cadmium and Lead sampled on 16 Oct 2001 (Test 6) were greater than the 1/100 of the TLV by about 100%. Table 5.3-6 below gives a summary of those analytes that were detected. A list of all metals that were monitored is shown in Tables EX 16 through EX 20 of the CHPPM Report²⁷ in Appendix B of this report.

Table 5.3-6. Metal Concentrations Summary

Target Analyte	CAS Number	Concentration (µg/m³)				1/100 of
		Location near Pile				TLV ^a (µg/m³)
		Front	Left	Right	Top	
BACKGROUND	10 Aug 01					
Aluminum (Al)	7429-90-5	0.32129	0.19281	0.15165	0.07373	100.0
Calcium (Ca)	7440-70-2	0.41342	0.34871	0.30236	0.24973	20 ^b
Copper (Cu)	7440-50-8	0.07352	0.09087	0.06927	0.07969	2.0
Iron (Fe)	7439-89-6	0.66835	0.43174	0.37912	0.26252	50 ^d
Magnesium (Mg)	7439-95-4	0.09214	0.05996	0.05944	<0.02557	100 ^e
Potassium (K)	7440-09-7	0.13081	0.12223	0.12029	0.09759	N/A ^g
Sodium (Na)	7440-23-5	0.77051	0.77445	0.79194	0.73045	N/A ^g
Zinc (Zn)	7440-66-6	0.04678	0.03598	0.04119	0.03281	100 ^f
TEST 1	16 Aug 01					
Calcium (Ca)	7440-70-2	0.34810	0.27953	0.30986	0.32351	20 ^b
Copper (Cu)	7440-50-8	0.04138	0.03638	0.03678	0.03813	2.0
Iron (Fe)	7439-89-6	0.15871	0.12342	0.13884	0.03813	50 ^d
Potassium (K)	7440-09-7	0.18987	0.15105	0.15723	0.15924	N/A ^g
Sodium (Na)	7440-23-5	0.76532	0.72485	0.69466	0.66966	N/A ^g

^a TWA taken from: Threshold Limit Values for Chemical Substances and Physical Agents, ACGIH, 2000.

^b The TLV for Calcium oxide [1305-78-8] was assumed.

^d The TLV for Iron oxide, dust and fume (Fe₂O₃) [1309-37-1], as Fe was assumed.

^e The TLV for Magnesium oxide fume [1309-48-4] was assumed.

^f The TLV for Zinc oxide dust [1314-13-2] was assumed.

^g N/A: No TLV data available.

Note: The "<" indicates that the compound was not quantified above the analytical detection limit for that sample. Bold type indicates that the result was greater than 1/100 of the TLV. Bold type indicates the highest concentration of each analyte.

FINAL

Table 5.3-6. Metal Concentrations Summary (Cont'd)

Target Analyte	CAS Number	Concentration (µg/m ³)				1/100 of TLV ^a (µg/m ³)
		Location near Pile				
		Front	Left	Right	Top	
TEST 2	5 Sept 01					
Aluminum (Al)	7429-90-5	0.15867	0.17573	0.13666	0.24887	100.0
Calcium (Ca)	7440-70-2	0.51720	0.54111	0.49822	0.68538	20 ^b
Copper (Cu)	7440-50-8	0.09353	0.12322	0.06672	0.09826	2.0
Iron (Fe)	7439-89-6	0.23104	0.22412	0.18831	0.35841	50 ^d
Lead (Pb)	7439-92-1	<0.02784	<0.02679	<0.02690	0.19011	0.5
Magnesium (Mg)	7439-95-4	0.14920	0.15269	0.13236	0.15801	100 ^e
Potassium (K)	7440-09-7	0.12294	0.11474	0.10267	0.16048	N/A ^g
Sodium (Na)	7440-23-5	0.39899	0.43396	0.37169	0.40902	N/A ^g
Zinc (Zn)	7440-66-6	0.04454	0.03590	0.03820	0.08740	100 ^f
TEST 6	16 Oct 01					
Aluminum (Al)	7429-90-5	0.07680	0.06000	0.06623	0.06659	100.0
Barium (Ba)	7440-39-3	0.06232	0.02731	0.03291	0.19657	5.0
Cadmium (Cd)	7440-43-9	0.06144	0.03807	0.03966	0.23166	0.1
Calcium (Ca)	7440-70-2	0.37654	0.36706	0.35858	0.35606	20 ^b
Chromium (Cr)	7440-47-3	<0.02633	<0.02483	<0.02531	0.03190	5 ^c
Copper (Cu)	7440-50-8	0.09523	0.05504	0.04851	0.12719	2.0
Iron (Fe)	7439-89-6	0.18125	0.08690	0.11179	0.17265	50 ^d
Lead (Pb)	7439-92-1	0.17467	0.13739	0.14217	0.92664	0.5
Magnesium (Mg)	7439-95-4	0.21109	0.12415	0.13668	0.26117	100 ^e
Mercury (Hg)	7439-97-6	0.00007	<0.00005	<0.00005	0.00005	0.25
Potassium (K)	7440-09-7	0.05705	0.04428	0.04219	0.17903	N/A ^g
Zinc (Zn)	7440-66-6	0.08953	0.05131	0.04894	0.15391	100 ^f

^a TWA taken from: Threshold Limit Values for Chemical Substances and Physical Agents, ACGIH, 2000.

^b The TLV for Calcium oxide [1305-78-8] was assumed.

^c The TLV for Chromium as Cr metal and Cr III compounds was assumed.

^d The TLV for Iron oxide, dust and fume (Fe_2O_3) [1309-37-1], as Fe was assumed.

^e The TLV for Magnesium oxide fume [1309-48-4] was assumed.

^f The TLV for Zinc oxide dust [1314-13-2] was assumed.

^g N/A: No TLV data available.

Note: The "<" indicates that the compound was not quantified above the analytical detection limit for that sample. Bold type indicates that the result was greater than 1/100 of the TLV. Bold type indicates the highest concentration of each analyte.

FINAL

Particulate Matter. All of the particulates were quantified above the detection limit. Of those the four of them were found to be greater than 1/100 of the TLV. Those were the PM_{2.5} on 5 Sept 2001 Top samplers, PM_{2.5} on 16 Oct 2001 Top and Front samplers, and the PM₁₀ on 16 Oct 2001 Top samplers. Table 5.3-7 shows a summary of the analytes detected. A complete list of all particulate information is shown in EX 26 through EX 30 of the CHPPM Report²⁷ in Appendix B of this report.

Table 5.3-7. Particulate Concentrations Summary

Target Analyte	CAS Number	Concentration (µg/m³)				NAAQS ^a (µg/m³)
		Location near Pile				
		Front	Left	Right	Top	
BACKGROUND	10 Aug 01					
PM ₁₀		30.7	27.6	27.0	27.7	150
PM _{2.5}		6.63	21.1	15.3	23.5	65
TSP		48.5	40.6	35.6	29.9	N/A ^b
TEST 1	16 Aug 01					
PM ₁₀		34.1	28.5	26.2	98.1	150
PM _{2.5}		18.3	15.5	17.1	63.0	65
TSP		37.1	34.5	31.0	41.3	N/A ^b
TEST 2	5 Sept 01					
PM ₁₀		13.3	14.3	21.6	136.3	150
PM _{2.5}		1.1	0.3	0.82	179.1	65
TSP		18.8	21.1	27.4	71.8	N/A ^b
TEST 6	16 Oct 01					
PM ₁₀		95.1	47.5	34.2	154.4	150
PM _{2.5}		304.3	24.4	19.8	327.6	65
TSP		83.7	47.3	38.3	117.4	N/A ^b

^a National Ambient Air Quality Standards (NAAQS), USEPA, Office of Air Quality Planning and Standards (OAQPS), 2002.

^b TSP is no longer a listed criteria pollutant in the NAAQS. However, as an indicator, the NAAQS Primary Standard for TSP was 260 $\mu\text{g}/\text{m}^3$, established in 1971, USEPA 600/P-95/001AF, April 1996.

Note: Bold and italicized type indicates that the result was greater than NAAQS.

Conclusion. Based on the ambient air sampling results, the concentrations of all compounds were below the standard, either 1/100 TLV or the NAAQS with the exception of particulates (PM₁₀ and PM_{2.5}) and metals (Cadmium and Lead). The following sample exceeded the NAAQS of 150 µg/m³ for PM₁₀: 16 October 2001 the Top Site sample was 154.4 µg/m³. The following samples exceeded the NAAQS of 65 µg/m³ for PM_{2.5}: 5 September 2001 test, the Top Site PM_{2.5} sample was 179.1 µg/m³, 16 October 2001 test, Top Site PM_{2.5} sample was 327.6 µg/m³, and 16 October 2001 Front Site PM_{2.5} sample was 304.3 µg/m³. The following sample exceeded the 1/100 TLV of 0.1 µg/m³ for Cadmium: 16 October 2001, the Top Site Cadmium sample was 0.23166 µg/m³. The following sample exceeded the 1/100 TLV of 0.5 µg/m³ for Lead: 16 October 2001, the Top Site Lead sample was 0.92664 µg/m³. These results are summarized in Table 5.3-1 through 5.3-7 above. The increased level of particulate matter may be attributable to the material of the thermal blanket decomposing during the HGD process. Higher measured concentrations from the Top Site would seem to indicate that aerodynamic particulates were carried upward by the convective heat from the pile. This activity was observed during the field tests and documented in Table 5.3-8.

Table 5.3-8. Summary of Samples Which Exceeded the Standard.

Sample Date	Sample Type	Analyte	Sample Concentration (µg/m ³)	NAAQS ¹ (µg/m ³)
TEST 2	Particulate	PM _{2.5}	179.1	65
TEST 6	Particulate	PM ₁₀	154.4	150
TEST 6	Particulate	PM _{2.5}	327.6	65
TEST 6	Particulate	PM _{2.5}	304.3	65
TEST 6	Metals	Cadmium	0.23166	0.1 ²
TEST 6	Metals	Lead	0.92664	0.5 ²

¹ National Ambient Air Quality Standards (NAAQS), USEPA, Office of Air Quality Planning and Standards (OAQPS), 2002.

² 1/100 of TWA taken from: Threshold Limit Values for Chemical Substances and Physical Agents, ACGIH, 2000.

5.4 PRE-TEST BACKGROUND SOIL SAMPLES AND RANGE SCRAP

5.4.1 Background Soil Samples

To establish a baseline of comparison for the performance assessment, several types of sample matrices and chemical analyses were undertaken prior to the HGD operation and demonstration test. Soil samples of the ground underneath the demonstration site, samples of range scrap, and ambient air were monitored to establish the baseline. The actual before demonstration duplicate sub-samples and the average metals concentrations are presented in Table 5.4-1.

FINAL

Table 5.4-1. Metals Results & Average For Before Test Soil Samples

Element	Symbol	Sample 1 (mg/Kg)	Sample 2 (mg/Kg)	Sample 3 (mg/Kg)	Average Results (mg/Kg)
Aluminum	Al	10861.6	13590.2	13224.4	12554.9
Antimony	Sb	<10.0	<10.0	<10.0	<10.0
Arsenic	As	<10.0	<10.0	<10.0	<10.0
Barium	Ba	39.010	48.200	48.214	45.129
Beryllium	Be	<10.0	<10.0	<10.0	<10.0
Boron	B	<10.0	<10.0	<10.0	<10.0
Cadmium	Cd	<10.0	<10.0	<10.0	<10.0
Calcium	Ca	430.30	546.60	536.31	504.24
Chromium	Cr	12.871	16.600	16.865	15.441
Cobalt	Co	<10.0	<10.0	<10.0	<10.0
Copper	Cu	15.842	19.000	19.643	18.158
Iron	Fe	12080.6	14281.4	14029.2	13460.6
Lead	Pb	35.050	40.200	41.270	38.834
Magnesium	Mg	1291.5	1510.4	1470.6	1423.9
Manganese	Mn	183.56	244.00	236.11	221.14
Molybdenum	Mo	<10.0	<10.0	<10.0	<10.0
Nickel	Ni	10.495	13.200	14.683	12.790
Potassium	K	568.32	892.00	861.11	773.36
Selenium	Se	<10.0	<10.0	<10.0	<10.0
Silver	Ag	<10.0	<10.0	<10.0	<10.0
Sodium	Na	176.04	147.40	126.19	149.90
Strontium 88	Sr	<10.0	<10.0	<10.0	<10.0
Thallium 205	Tl	<10.0	<10.0	<10.0	<10.0
Vanadium 51	V	17.786	21.070	21.661	20.168
Zinc	Zn	36.634	42.000	58.730	45.792

Note: Analysis for mercury was inadvertently eliminated from the elements list and was not performed. The after demonstration soil sample will be analyzed for mercury and if any is detected another background sample from ABR-9 will be taken and analyzed for metals.

FINAL

The actual before demonstration samples from the soil analyses for explosives are presented in Table 5.4-2.

Table 5.4-2. Explosives Results For Before Test Soil Samples

Baseline Soil Sample -Explosives	HMX (mg/kg)	RDX (mg/kg)	TNT (mg/kg)
Sample 1	<0.04	<0.04	<0.04
Sample 2	<0.04	<0.04	<0.04
Sample 3	<0.04	<0.04	<0.04

5.4.2 Range Scrap

Prior to covering the first test pile, eleven samples (surface wipes, and small pieces scraped from surfaces) were collected from the range scrap pile. Most of the samples were taken from surfaces that gave a positive response to Expray® kit wipe samples (second can "Nitramines/nitrate esters"). The acquisition method and the explosive detection data are presented in Table 5.4-3.

Table 5.4-3. Explosive Detection On Range Scrap

Sample Label	Acquisition Method	Description of Item	Explosives Detected using Expray®
A	Q-Tip Wipe	Metal Disk Used To Fill 155mm Inert Round	No
B	Q-Tip Wipe	Reactive Armor Tile Cover	Yes
C	Q-Tip Wipe	Reactive Armor Tile Cover	Yes
D	Q-Tip Wipe	Reactive Armor Tile Cover	Yes
E	Q-Tip Wipe	Inside of 250mm Inert Filled Bomb	No
F	Q-Tip Wipe	Reactive Armor Tile Cover White Range Residue/Paint On Surface	Yes
G	Paint Scraped Off Surface	Piece Of White Range Residue	No
H	Q-Tip Wipe	Reactive Armor Test Box, Black Coated White Residue/Paint On Surface	Yes
I	Q-Tip Wipe	Reactive Armor Test Box, Black Coated White Residue/Paint On Surface	Yes
J	Paint Scraped Off Surface	Piece Of Black Coated White Range Residue	No
K	Q-Tip Wipe	Witness Plate	No

FINAL

The eleven samples were analyzed for explosive residues using EPA Method 8330 HPLC which frequently established the presence of NG, TNT, RDX and HMX. The results of the analyses are presented in Table 5.4-4.

Table 5.4-4. Explosives Detected On Scrap

Sample Label	NG (mg/L)	TNT (mg/L)	RDX (mg/L)	HMX (mg/L)
A	0.08	ND	ND	ND
B	ND	0.01	530	9.5
C	14	ND	2.4	14
D	ND	ND	27	8.7
E	ND	0.10	59	10
F	ND	0.06	86	12
G	ND	ND	25	ND
H	ND	ND	0.66	11
I	0.6	ND	ND	11
J	ND	ND	ND	ND
K	0.6	ND	ND	0.6

In addition, after the demonstration tests were completed, the thermal blankets were analyzed for metals and explosives. Ten random samples were taken from the used thermal blankets revealed no detectable amounts of metals or explosives.

Even though the piles were usually formed several days prior to the start of testing, the concaved portions of the cut opened shells still retained a significant amount of water. Prior to dumping out one of the dumpsters, a water sample was taken and sent to CRREL Labs for explosives analysis using EPA Method 8330 HPLC. The results are presented in Table 5.4-5.

Table 5.4-5. Explosives Detected In Dumpster Water

Dumpster Water Sample	HMX (mg/L)	RDX (mg/L)	TNT (mg/L)
Sample 1	0.43	0.97	<0.005

FINAL

5.5 HEALTH HAZARD ASSESSMENT - HANDLING OF INSULATION BLANKET

The ATC Industrial Hygiene Section provided a Preliminary Health Hazard Assessment of the handling, installation, and removal of the high temperature insulation blanket. The purpose of this survey was to evaluate exposure to respirable dust while handling insulation material used for the transportable HGD system. Personnel are required to apply new insulation, replace damaged insulation, install or repair thermocouples, remove or replace test coupons, and remove and bag the insulation when the pile is ready for disassembly. During these activities, there is a visible release of fibers. There were no engineered controls (such as dust control agents or water spray) used during these work activities in the demonstration test.

Personal air samples for total fiber count and respirable dust were taken by monitors placed on the range technician's person while working.

Insulation blankets from three manufacturers were used for the test. The insulation primarily consists of two types of man-made fibers: one manufactured of fiberglass material (BGF Mat by BGF Industries) and a second manufactured of calcium magnesium silicate and silica (Silmat by Ametek). One roll of insulation containing refractory ceramic fibers (Cerablanket by Thermal Ceramics) was also tested.

The blankets have temperature limitations that should not be exceeded to avoid changing its composition and creating a respiratory hazard. During some test burns, the temperature of the scrap pile has exceeded the recommended temperature value for the blankets. These blankets are easily identified by changes in texture and color.

5.5.1 Heath Hazard Data

Results for personal air sampling are presented in Table 5.5-1. Personal air samples for respirable dust were taken on 10 Oct 01 while range technicians disassembled and bagged insulation blankets exposed to multiple pile burns. The 8-hour time-weighted averages (TWAs) were <0.06 and 0.15 milligrams per cubic meter (mg/m^3). These results are below the occupational exposure limit (OEL) of $3 \text{ mg}/\text{m}^3$ (Ref. 28).

Personal air samples for total fiber count and respirable dust were taken on 15 Oct 01 while technicians assembled new insulation over a test pile. The 8-hour TWAs were 0.036 fibers per cubic centimeter (f/cc) and $<0.06 \text{ mg}/\text{m}^3$, respectively. These results are below the OELs of 1 f/cc and $3 \text{ mg}/\text{m}^3$ (Ref. 28). A risk assessment code of 3 has been assigned to this work activity. This code indicates a moderate risk to employees working at this site.

FINAL

Table 5.5-1 Industrial Hygiene Air Sampling Results

Sample Number	Person Monitored	Sample Date	Chemical Monitored & sampling Time	Results mg/m ³ f/cc PPM 8 hr TWA/C/STEL	PEL/ TLV mg/m ³ f/cc PPM	Action Level (AL) Exceeded
01C-258	Range Technician	10 Oct 01	Respirable Dust 95 mins	<0.06	3.0	No
01C-259	Range Technician	10 Oct 01	Respirable Dust 155 mins	0.15	3.0	No
01C-264	Range Technician	15 Oct 01	Synthetic vitreous fiber count, total 143 mins	0.036 f/cc	1 f/cc	No
01C-266	Range Technician	15 Oct 01	Respirable Dust 145 mins	<0.06	3.0	No
S01C-274	Range Technician	6 Nov 01	Respirable dust (43 mins)	<0.06	3	No
S01C-275	Range Technician	6 Nov 01	Respirable dust (43 mins)	<0.06	3	No

TABLE KEY

mg/m³: Milligrams per cubic meter

f/cc: Fibers per cubic centimeter

ppm: Parts per million

TWA: (Time weighted average): An average value weighted in terms of the actual time that it exists during a given time interval.

C: (Ceiling value): An exposure which cannot be exceeded for any length of time.

STEL: (Short-term exposure limit): A 15 minute (30 minute for asbestos) TWA exposure which should not be exceeded at any time during a work day.

PEL: (Permissible exposure limit): The maximum permissible concentration of a toxic chemical or exposure level of a harmful physical agent (normally averaged over an 8-hour period) to which an employee may be exposed.

TLV: (Threshold limit value): The TWA concentration of a substance for a normal 8-hour work day and 40-hour work week, to which nearly all workers may be repeatedly exposed, day after day, without adverse health effects.

AL: (Action level): A value (usually 1/2 the PEL) at which corrective actions including medical surveillance must be implemented.

UCL: (Upper confidence limit): Determined by statistical methods incorporated into the sample results to obtain the highest value the true exposure could be with a high degree of confidence. If the measured results do not exceed the standard and the UCL does not exceed the standard, we can be 95 percent confident that the employer is in compliance with the standard.

LOQ: (Limit of quantitation): Term used by analytical laboratory to define the lowest level that a numerical value can be assigned.

FINAL

On 6 Nov 01, another survey was conducted to evaluate exposure to respirable dust while handling insulation material used for the subject test. Used insulation blankets were removed from storage bags, rolled out and inspected. The blankets were laid onto the test mound.

The 8-hour time-weighted averages for respirable dust were both <0.06 milligrams per cubic meter (mg/m^3). These results are below the occupational exposure limit of $3 \text{ mg}/\text{m}^3$. A risk assessment code of 3 was been assigned. This code indicates a moderate risk to employees working at this site.

Surface samples of fiberglass insulation (BGF Mat, manufactured by BGF Industries) were taken using a low volume suction pump on the exposed surface of the insulation that had been on the test pile through a complete test phase. The samples consisted of 95-100 percent fiberglass fibers and trace amounts of plant (cellulose) material, quartz, and calcite chips. This indicates that the fibers are easily released into the air with minimal surface interaction.

5.5.2 Data Assessment and Recommendations for Personal Protective Equipment

Action Levels were not exceeded in any personal monitoring event. Action levels are the value (usually $1/2$ the Permissible Exposure Limit) at which corrective actions including medical surveillance must be implemented.

ATC Industrial Hygiene recommends that all personnel required to handle the insulation blankets shall wear approved respiratory protection and coveralls to protect their personal clothing. Gloves and long sleeves shall be worn. Personnel shall wash their hands, face, and neck immediately after handling the insulation.

At ATC, personnel performing removal and application of blankets are required to wear full-face negative air purifying respirators with high efficiency particulate air filters, gloves, disposable coveralls, and safety shoes. Personnel repairing or replacing thermocouples and test coupons wear leather gloves and safety shoes.

During assembly and removal of insulation blankets, all non-essential personnel should be stationed in a safety zone no closer to the test pile than the gravel road (30 feet). Dependent upon the wind speed and direction, the safe zone may need to be expanded.

The grounds in the immediate area around the HGD site should be kept clean by routine grounds keeping by collecting and bagging loose insulation that has broken free of the pile and is lying on the ground.

Also, use of engineered controls (dust control agents or water spray) on the insulation prior to handing, installation, or removal is highly recommended, and will mitigate the health hazard to range technicians.

The Cerablanket® (manufactured by Thermal Ceramics Inc. contains refractory ceramic fibers, which can potentially cause lung cancer with continuous exposure. It is required that the use of the Cerablanket® be discontinued immediately.

5.6 HGD SYSTEM PERFORMANCE ASSESSMENT

Only seven tests were completed of the twelve that were planned as stated in the Final Demonstration Plan¹⁷ (Appendix B). As explained in a correspondence from USAEC and ATC to ESTCP dated 7 December 2001:

FINAL

“the Hot Gas Decontamination Team (USAEC, ATC and Parsons) has stopped testing on the current HGD system after completing 7 of the 12 planned tests. We believe that the testing on the current HGD configuration was a success. Testing was a success in that we achieved the technical and performance objectives stated in the Final Demonstration Plan¹⁷ (Appendix B), and proved that the concept worked and could be used in the configuration tested. Specifically, once the pile reached its predetermined temperature and soak time, the spiked coupons were cleaned of all explosive contamination. Decontamination was accomplished by reaching 500°F with 3 hours soak time or 600°F with two hours of soak time. The density of the pile determined the time needed to reach the predetermined temperature. Preliminary data shows that a less dense pile – that contained reactive armor tile pieces and some split open large caliber projectiles – took 3- 4 hours to heat –up, whereas a more dense pile – made up of split open large caliber projectiles – took up to 8 hours to heat up.”

In seven tests, the performance objectives stated in Table 3.1-1 of the Final Demonstration Plan¹⁷ (Appendix B) were achieved (or are under review by regulators). An itemized list of performance objective and level of success is presented in Table 5.6-1

Table 5.6-1 Performance Objectives And Assessment

Type of Performance Objective	Primary Performance Criteria	Expected Performance (Metric)	Performance Assessment
Quantitative	1. Prove HGD decontamination effective to remove or destroy explosive contaminants	No detectable amount of explosives on spiked coupons	Objective Achieved: no detectable explosives in spiked coupons
	2. Prove HGD equipment meets performance criteria	Thermocouples and control system measure and record time and temperature	Objective Achieved:Thermocouples, controls, and data recording worked excellent.
	3. Meeting regulatory standards for fugitive emissions	MDE determined based on data collected	Objective Achieved:Fugitive emissions were minor and tolerable.
	4. Low cost per ton	<\$300/ton	Startup Operation \$181/Ton Full-Scale Production \$91/Ton
Qualitative	1. Reduce HGD operating costs	Shorter time for decontamination - Less than 8 hour work day.	Objective Achieved: Decontamination Time reduced to 7 hours.
	2. Safe operation of the system	No serious injuries	Objective achieved: no injuries experienced
	3. Ease of use	Operator acceptance	Objective achieved: burner and controls easy to operate: however, insulation gave off nuisance dust.

In summary, the results of the first three demonstration tests allowed the test team to substantially accelerate the stepwise approach set forth in the test matrix Table 4.2-1 in the Final

FINAL

Demonstration Plan¹⁷ (Appendix B), such that fewer tests were required to meet the test objective to reduce time and operating cost for successful decontamination. As a result, only 7 tests were required to prove the optimum time and temperature for successful decontamination.

In addition, test specific objectives as stated in the test matrix Table 4.2-1 of the Final Demonstration Plan¹⁷ (Appendix B) were achieved in seven tests as shown in Table 5.6-2.

Table 5.6-2 Test-Specific Objectives And Assessment

Test Specific Objective	Performance Assessment
Shorten run time	Objective Achieved: Run time shortened to 7 hours including a 3 hour soak at 500°F.
Decrease Soak Temperature	Objective Achieved: Temperature was decreased to 500°F from 600°F
Validate results /redo	Objective Achieved: Results were repeated and validated.
Optimize pile size	Objective Achieved: Pile size at 14.5 tons was optimal for processing in a regular 8-hour work day.
Optimize insulation:	Objective Achieved: Insulation thickness of 1-1/2 inches to 2 inches is optimal and insulation types and products identified.

A system-by-system performance assessment is presented as follows.

Burner System

The burner system performed very well and was sized appropriately for the job. The burner had the capability to overheat the insulation past the manufacturer's maximum recommended operating temperature for the insulation, and consequently the burner was throttled back during the tests (automatically throttled back by the high temperature limit setting of the control system).

HGD of Pile 1 weighing 14.5 tons was completed in seven hours versus 11 to 12 hours for Pile 2 weighing 20 tons. Since completing work in a regular eight hour shift is desirable (no premium overtime cost), then 15 tons is considered an optimal size pile for the transportable HGD system.

Control System

The instrumentation and control system including the wireless remote control transmitting and receiving units performed well. The wireless remote control system was very reliable overall, despite an occasional signal lapse. During early tests, bouncing of the control system causing the burner to sequence on-and-off is considered normal for startup of a new system, and was solved by tuning of the control system.

FINAL

The control system and programming was user friendly and easily learned by non-technical operators. The Data Acquisition System component of the control system reported results that were readily assimilated and reported. There are no recommended changes to the control system.

Thermocouples failed at high temperature locations, and extra care must be exercised to protect the thermocouple lead wires from the high heat. In earlier tests, thermocouples failed at high temperature location near the burner (used to protect the insulation blanket) when not enough care was taken to protect the lead wires. To protect the thermocouple lead wires from the heat, the lead wires must be run on the outside of the insulation and around the pile. Thermocouples were observed to fail, and later come back to life in what is an unexplained phenomenon.

Thermal Insulation and Thermal Blanket

Several thermal insulation products and one thermal blanket product were tested as summarized as follows:

- Un-shrunk Silmat™ AB100U (raw silica based fiber mat by Ametek) - too fragile to install, could not support its own weight, and ripped when lifted. Silicone fiber fugitive dust emitted to the air was a respiratory hazard, skin irritant, and nuisance to installer personnel.
- Shrunk Silmat™ AB50S and AB100S (Silica based fiber mat that had been heat-shrunk at the factory) – This product had substantially more strength, and emitted less dust than the unshrunk. This product was light and easy to handle, but still emitted fugitive and nuisance dust, such that PPE was required by installers. This product was the most effective for the front (hottest) half of the pile closest to the burner. This product is more expensive than the unshrunk Silmat™ product.
- BGF Mat (high temperature fiberglass insulation manufactured by BGF Industries) – Less expensive, heavier than Silmat™, and appropriate for back half of the burner, or as an overcoat second layer over Silmat in the front half of the pile. PPE as required for installation of fiberglass insulation by installers.
- Cerablanket (aluminosilica based insulation manufactured by Thermal Ceramics) – The health hazards listed in the product's MSDS led the ATC Industrial Hygiene Section to discontinue use of this product. Not recommended for future use.
- Superwool (a non-toxic environmentally friendly product by Thermal Ceramics) – Product reportedly subject to water damage. One roll used was insufficient to make adequate evaluation.

More than one 1-inch layer of insulation blanket will facilitate faster processing of scrap.

Insulation that is either 1-1/2 inches or 2 inches thick will enhance production rates substantially. A one inch high slit in the insulation blanket along the ground around the back end of the pile assists in directing heat to the back of the pile.

Stainless steel welded wire mesh was used underlying the insulation blanket to protect it from the jagged scrap pieces during installation and removal. The stainless mesh also formed a flexible (moldable) interface between the burner (burner shroud) and the irregular pile, directing the heat from the burner into the shroud. The steel mesh held up remarkably well considering

the temperatures experienced, and was still in reusable condition after the final test. The chicken wire overlaying the insulation effectively held the insulation down in place, keeping it from moving due to slumping or wind or rain.

The pre-fabricated tent spikes worked very well to secure the chicken wire to the ground, which in turn secure the thermal insulation and thermal blanket to the pile. The pre-fabricated spikes (one foot long heavy rebar) were larger than needed, and smaller landscape nails could have been used.

5.7 TECHNOLOGY COMPARISON

The transportable HGD system in a blanket-on-pile configuration was compared with two similar and competing types of facilities for range scrap treatment that are currently available as follows:

- A permanent fixed-facility HGD as reported in "Demonstration Results of Hot Gas Decontamination for Explosives at Hawthorne Army Depot (Final)"⁹.
- A transportable HGD furnace as reported in "Validation Test Report for the Transportable Hot-Gas Decontamination System Used to Support the Decontamination of Explosives contaminated Piping and Debris"¹².

A head-to-head comparison of the technical characteristics of the transportable HGD system in a blanket-on-pile configuration versus the fixed HGD facility and transportable HGD furnace is presented in this section. Refer to Section 6 for a cost comparison of the three technologies. A line-by-line comparison of the three types of HGD facilities is presented in Table 5.7-1.

The permanent fixed facility would be constructed on-site at the location of the scrap generation for this comparison. When compared to the permanent fixed facility, the transportable *in situ* blanket-on-pile configuration is simple and fully transportable while the permanent fixed HGD facility includes a permanent building and infrastructure; requires substantial environmental permitting; and has higher operating capacity. The permanent nature of the facilities results in much higher cost for permanent structures and utilities (see Section 6). The transportable HGD system has temporary and transportable utilities, and when processing is complete leaves vacant ground. The transportable blanket-pile system has no emissions point source and no off-gas treatment system, and consequently is less complex, easier to operate and maintain, and less expensive in this area (see Section 6).

When compared to the transportable HGD furnace, the blanket-on-pile configuration has considerably higher production rate and is operated one shift, five days per week. The disadvantages of the transportable HGD furnace are its small capacity per load cycle (at 1.5 tons per load cycle), and the need to operate 24 hours per day, seven days per week to achieve reasonable production rate. This in turn drives the operating cost upwards for operating the transportable HGD furnace (see Section 6). Again, the transportable blanket-pile system has no emissions point source and no off-gas treatment system, and consequently is less complex, easier to operate and maintain, and less expensive for capital and operating cost in this area.

FINAL

Table 5.7-1 Technology Comparison

	Permanent Fixed Facility	Transportable HGD Furnace	Transportable In-situ HGD
Type	Permanent fixed facility using HGD furnace	Transportable HGD furnace	Transportable Skid-mounted burner and insulation blanket
Handling/feed	Placed in furnace feed tray.	Placed in furnace feed tray.	In place; pile on ground
Off-Gas treatment	Thermal oxidizer.	Thermal oxidizer.	None; no stack.
Off-gas Monitoring	Continuous emissions monitoring.	Continuous emissions monitoring.	Ambient air monitoring may be required.
Environmental permitting	Air emissions permit and RCRA Part B permit required	Varies from state-to-state; air emissions permit may be required based on volume.	Varies from state-to-state; air emissions permit may be required based on volume.
Utilities/infrastructure	Fixed electrical and fuel oil supply; permanent buildings and sanitary facilities.	Fixed or temporary electrical; propane tanks; temporary control trailer and sanitary facilities.	Temporary electrical and propane; temporary control trailer and sanitary facilities.
Operators	2 full time	8 full time	2 full time
Working day	8 hours per day; unattended on off-shifts; 5 days per week	24 hours; full attended three shifts per day; 7 days per week	8 hours per day; unattended on off-shifts; 5 days per week
Cycle Time	Hot 24 hours; with cooldown 48 hrs.	24 hours per day	Hot 8 hours; with cooldown 24 hrs.
Tons per cycle	27.4 Tons per cycle	1.5 Tons	20 Tons per cycle
Cycles per week	3 per week	28 per week	5 per week; every workday
Tons per day	16.4 Tons	6 Tons	15 to 20 Tons
System Transportation	NA	Three low boy tractor trailers	One short bed flatbed truck.
Capital Cost¹	High	Medium	Low
Operating Cost¹	High if cost of transportation to off-site fixed facility is included.	Medium	Low

1. See Cost Assessment Section 6 for more detail and comparison.

6.0 Cost Assessment

This section provides an assessment of the expected operational costs when the transportable HGD system is implemented in a full scale and large scale production scenario. To accomplish this goal, capital equipment costs, rental equipment, consumable costs, mobilization costs, site preparation costs, system shakedown and set-up costs, operating cost, emissions cost, and disposal costs were used from the HGD demonstration tests.

6.1 EXPECTED OPERATIONAL COST

Actual costs from the HGD demonstration were used as the basis for capital and operating costs for an expected operational scenario. It is noted that some equipment used for the demonstration test was government-furnished equipment, such as the Operator Workstation Trailer and the electric power generator, and consequently direct costs from the demonstration test were not available. Costs for these items are accounted for in the operational cost for the system as presented in Section 6.1.2 below. More detail on cost for the demonstration test is presented in the Cost and Performance Report²⁹ for the project.

6.1.1 Cost Data from Demonstration Test

Capital Equipment Costs. Capital equipment costs provided below are for the skid-mounted, transportable HGD system procured by ATC for USAEC in the fiscal year 2001. The burner control system supplied with the HGD system is capable of local and remote operations utilizing a wireless remote system or a back-up hard wire system. The burner control system is also qualified to operate in National Electrical Manufacturers Association (NEMA 4x) and National Fire Protection Association (NFPA) conditions.

HGD System.

\$85,765.00

This system includes a 2.5 million Btu/hr propane-fired burner, burner controls, local and remote operations utilizing a wireless remote system with a back-up hard wire system, and an operator workstation. Additionally, the system can be operated off of a 20-kilowatt generator or house supplied power.

Consumables. Consumable items for the HGD are the materials used to run the blower, fuel the burner, monitor the temperature in the pile, and thermally insulate the pile during the decontamination process that were eventually used up, or disposed of and replaced with new items. For HGD these consumable items included propane and diesel fuel, thermocouples and several types of wire mesh and thermal blankets.

Propane Fuel

\$220.00/Test

The average cost per gallon for propane that was collected in the summer of 2002 was \$1.03 per gallon. An average of 213 gallons of propane was used per trial during the demonstration performed at ATC. Propane costs averaged \$220.00 per trial.

Diesel Fuel.

\$21.00/Test

The average cost per gallon for diesel fuel that was collected in the summer of 2002 was \$1.24 per gallon. An average of 16.37 gallons of diesel was used per trial during the demonstration performed at ATC. Diesel costs averaged \$21.00 per trial.

FINAL

Thermocouples.

\$212.00/Test

During the seven trials 8 of the thermocouples were replaced. The replacement cost of the thermocouples was \$185.20. So, on average thermocouples costs were \$212.00 per trial.

Miscellaneous Maintenance Parts.

Cost Included

During the burner shakedown phase and during the seven trials, 2 fuses, 1 igniter and one pressure switch were replaced. All of these items were warranted by the manufacturer at no additional cost to the government, although the actual costs per item are shown in Table 6.1-1 for information only.

Table 6.1-1. Miscellaneous Maintenance Parts Used in Demonstration Test.

Item Description	Cost
8 Amp Fuses (2 each)	\$16.00
Igniter	\$68.00
Pressure Switch	\$327.57

Pile Insulation. The actual wire mesh and thermal blankets procured at the start of the HGD demonstration and their associated costs are shown in the Table 6.1-2.

Table 6-1.2. Insulation Used in Demonstration Test.

Item Description	Quantity	Cost/ft ²	Total Cost
Silmat™ ½" thermal blanket- unshrunk	300 ft ²	\$2.55	\$765.00
Silmat™ ½" thermal blanket -shrunk	575 ft ²	\$3.52	\$2,024.00
Silmat™ 1" thermal blanket - unshrunk	450 ft ²	\$4.85	\$2,182.50
Siltemp™ High Temp. thermal blanket	300 ft ²	\$4.22	\$1,266.00
BGF™ Mat	900 ft ²	\$0.73	\$843.90
Stainless Steel 2 Mesh	400 ft ²	\$2.05	\$818.00
Carbon Steel 2 Mesh	800 ft ²	\$0.52	\$832.00
Galvanized Steel Reverse Twist	1200 ft ²	\$0.18	\$214.64
TOTAL COSTS			\$8,946.04

Pile Insulation.

\$1,454.00/Test

During the HGD demonstration, trials 1 through 5 utilized a pile consisting of 14.5 tons of scrap that measured 18' long by 20' wide by 7' high and trials 6 and 7 utilized a pile consisting of 20 tons of scrap that measured 23.7' long by 13.7' wide by 6 feet high. The total square footage and associated costs per trial to insulate a pile is shown in Table 6.1-3 and the average cost over seven trials to insulate a pile is shown in Table 6.1-4. Based on the information gathered over the 7 trials an average cost of \$1,454.00 to cover one pile was determined.

FINAL

Table 6.1-3. HGD Total Square Footage and Cost Per Trial.

Item	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7
Silmat™ ½" unshrunk	56 ft ²	45 ft ²	0 ft ²	0 ft ²	0 ft ²	0 ft ²	130 ft ²
	\$142.80	\$114.75	\$0.00	\$0.00	\$0.00	\$0.00	\$331.50
Silmat™ ½" shrunk	0 ft ²	0 ft ²	429 ft ²	146 ft ²	0 ft ²	0 ft ²	0 ft ²
	\$0.00	\$0.00	\$1,510.08	\$513.92	\$0.00	\$0.00	\$0.00
Silmat™ 1" - unshrunk	450 ft ²	0 ft ²	0 ft ²	0 ft ²	0 ft ²	0 ft ²	0 ft ²
	\$2,182.50	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
Siltemp™	85 ft ²	0 ft ²	0 ft ²	12 ft ²	0 ft ²	200 ft ²	0 ft ²
	\$770.80	\$0.00	\$0.00	\$50.64	\$0.00	\$844.00	\$0.00
BGF™ Mat	450 ft ²	101 ft ²	0 ft ²	0 ft ²	0 ft ²	125 ft ²	0 ft ²
	\$328.50	\$73.73	\$0.00	\$0.00	\$0.00	\$91.25	\$0.00
Stainless Steel Mesh	376 ft ²	0 ft ²	0 ft ²	0 ft ²	0 ft ²	0 ft ²	0 ft ²
	\$770.80	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
Carbon Steel Mesh	400 ft ²	0 ft ²	0 ft ²	0 ft ²	0 ft ²	0 ft ²	0 ft ²
	\$208.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
Galvanized Steel	168 ft ²	0 ft ²	0 ft ²	0 ft ²	0 ft ²	170 ft ²	0 ft ²
	\$30.24	\$0.00	\$0.00	\$0.00	\$0.00	\$30.60	\$0.00
Labor	16 man-hours	7 man-hours	15 man-hours	1.5 man-hours	0 man-hours	4.5 man-hours	4.5 man-hours
	\$720.00	\$315.00	\$674.00	\$67.50	\$0.00	\$202.50	\$202.50
Total Cost /Trial	\$5,153.64	\$503.48	\$2,184.08	\$632.06	\$0.00	\$1,168.35	\$534.00

FINAL

Table 6.1-4. HGD Average Cost Over Seven Tests.

Item	Totals
Silmat™ ½" thermal blanket -unshrunk	589.05
Silmat™ ½" thermal blanket -shrunk	2,024.00
Silmat™ 1" thermal blanket - unshrunk	2,182.50
Siltemp™ high temperature thermal blanket	1,665.44
BGF™ Mat	493.48
Stainless Steel 2 Mesh	770.80
Carbon Steel 2 Mesh	208.00
Galvanized Steel Reverse Twist	60.84
Labor (\$45/man-hour)	2,181.50
Total Costs	\$10,175.61
Average Cost /Test	\$1,453.66

System Shakedown and Start-up.

Cost Included

Approximately five people were involved in emplacing the equipment, connecting the burner to the propane and the diesel fuel and tweaking the system to perform as efficiently as possible. The week of training that was given by the manufacturer and was included in the cost of the burner and the operators were trained while decontaminating the first and second piles. The labor and materials it took to hook-up to the propane tanks was included in the price per gallon of the propane contract. The other costs, such as setting up the trailer and the generator are included in the mobilization costs. So, no dollar figure was assessed to the system shakedown and start-up.

Operating Costs.

Cost may vary from site to site, depending on the location of the selected site, local labor, and operating conditions. The operating costs for this cost analysis is based on a fixed labor rate of \$45.00 hour and a minimum of two operators present at all times.

Emissions Requirements.

Cost Vary/State

The regulatory controls pertaining to the implementation HGD system and the associated costs will vary from state to state. ATC was given permission from The Maryland Department of the Environment (MDE) to conduct the demonstration and collect the emissions data. To collect this emissions data, ambient air monitors were used during one background event and three trials during the ATC demonstration. The costs incurred were divided into two categories – field analysis and lab analysis. Each field analysis cost approximately \$5,600.00 and the lab analysis cost approximately \$8,300.00 per trial. The specifics for the emissions sampled for, the data

FINAL

collection methods and the analysis methods are spelled out in the fugitive emissions section of this report. No dollar figure was placed on emissions requirements for this cost assessment.

Disposal Costs.

Approximately 2000 pounds of thermal blankets were used up during the 7 trials performed during the HGD demonstrations. Analysis for metals and explosives from 10 random samples taken from the used blankets revealed that the blankets were free from explosives and metals and could be disposed of as a solid waste. Disposal costs as a solid waste (no explosives or metals) are approximately \$50.00, whereas disposal as a hazardous waste would be more expensive.

Cost Summary. A summary of line item costs incurred in the demonstration test is presented in Table 6.1-5. Costs for site preparation and emissions monitoring will vary from site-to-site and are not included.

Table 6.1-5. Cost Summary for Demonstration Test.

Cost Description	Itemized Cost	Cost
Capital Cost		\$85,765.00
-HGD System	\$85,765.00	
Consumables		\$1,907.00
-Propane Fuel	\$220.00	
-Diesel Fuel	\$21.00	
-Thermocouples	\$212.00	
-Miscellaneous Parts	\$0.00	
-Pile Insulation.	\$1,454.00	

6.1.2 Operational Cost

The actual costs from the HGD demonstration were supplemented by costs for rental equipment from budgetary cost proposals from vendors and RS Means Construction Cost Data³⁰ as the basis for capital and operating costs for an expected operational scenario. After optimizing the HGD system based on lessons learned during the HGD demonstration a startup full-scale production cost and a long term full scale production cost were developed. Note that each type of scrap metal encountered and location may have site specific or unique requirements, which will affect the overall cost projection to operate the HGD system.

Rental Items. Rental equipment costs are based on budgetary cost proposals from vendors and RS Means Construction Cost Data²⁹. Rental Equipment for the HGD system include an office trailer, a 20 Kw, 240 volt, AC, 3-phase diesel fueled trailer mounted generator, and a 500 gallon propane tank.

Operator Workstation Trailer.

\$365.00/month

The trailer is 10 feet by 44 feet with office space can be rented monthly for \$165.00 plus approximately \$200.00 for freight, blocking and leveling.

Portable Toilet.

\$100/month

Most portable toilet companies will rent for any time longer than one week and usually provide service to the portable toilet once a week.

Generator.

\$1200/month

FINAL

A 20Kw, 240 volt, AC, 3-phase diesel fueled trailer mounted generator average cost is \$1,200.00 per month to rent.

500-Gallon Propane Tank.

\$150.00/site

The data collected during the demonstration supported reducing the two 1000-gallon propane tanks to one 500-gallon tank. The propane tanks were vendor-furnished with the cost included in the cost per gallon of the propane. Initial freight and set-up costs were either a flat fee of \$150.00 or \$47.50 per man-hour of work on a site specific basis. The \$150.00 flat fee was used in this cost analysis.

Forklift

\$2,000/Month

One large rough terrain forklift is estimated to cost \$2,000 per month to rent.

Mobilization Costs

\$1,125.00/Move

Off-site mobilization costs will vary from site to site because of local conditions, labor costs, and equipment transportation costs. The HGD system was mobilized with one lowboy style tractor-trailer and one 10,000 lb rough terrain forklift. Table 6.1-6 shows the estimated cost incurred to move the HGD system 150 miles away to a different installation.

Table 6.1-6. Mobilization Cost Breakdown

Rental Item	Cost /day	Cost/mile	Miles	Total Hours	Total Cost
Tractor	\$90.00	\$0.10	150	8	\$105.00
Trailer	\$20.00	\$0.15	150	8	\$50.00
Forklift	\$250.00	\$0.00	150	8	\$250.00
Labor (\$45 /man-hours)	--	--	--	16	\$720.00
Total Mobilization Costs					\$1,125.00

Site Preparation.

Cost Vary/Site

Site preparation will vary from site to site because of location and installation safety regulations. At a minimum, the ground underneath each test pile and in the immediate vicinity of the test pile must be level and free of vegetation and debris. Vegetation and undergrowth should be cut and removed within 100 feet of the test pile. During the test at ATC, an additional firebreak made of gravel was required around the HGD site. No dollar figure was assessed to the site preparation.

Insulation System: The quantities and types of thermal insulation used on the pile were optimized during the demonstration tests based on lessons learned from test to test. Table 6.1-8 shows the optimized HGD insulation and wire materials quantities and associated costs that were derived from the demonstration tests.

FINAL

**Table 6.1-8. Operational HGD Insulation and Wire Materials
Quantities and Associated Costs**

Item	Quantity	Type	Cost/ ft ³	Total Cost/Item
Insulation	300 ft ³	½" Silica Mat	\$2.84	\$852.00
	700 ft ³	1" Fiberglass	\$0.73	\$511.00
			One Run Total Cost	\$1,363.00
			Cost per Run When Reused 3 Runs	\$454.00
Wire Materials	300 ft ³	Stainless Steel	\$2.05	\$615.00
	400 ft ³	Carbon Steel	\$0.52	\$208.00
	700 ft ³	Galvanized Steel	\$0.18	\$126.00
			One Run Total Cost	\$949.00
			Cost per Run When Reused 20 Runs	\$47.00

Startup Operational Costs

During startup and initial operation (the first few months approximately), it is expected that the transportable HGD will yield lower production rates than for the long term. With inexperienced operators learning the system simultaneously with the system being tuned for peak performance, it is expected that production would be lower than the long term with experienced operators. The startup production rate used for this operational scenario is the same as achieved in the demonstration tests (15 Tons per 8-hour day). The startup operation cost estimate was based on the following parameters:

- Operational costs incurred during demonstration tests
- Production rates achieved during demonstration tests
- The material quantities and associated costs shown in Table 6.1-8
- 11 runs per month - every other weekday
- 15 tons per run
- 2 operators/setup persons full time
- 1 run completed in 8- hour day.
- 1 setup completed in 8-hour day.

The breakdown of costs for a startup operations is shown in Table 6.1-9, indicating a processing cost of \$181 per ton (not including capital cost which is fully recoverable as a transportable system, and not including ambient air monitoring).

FINAL

Table 6.1-9. Startup Operations Cost Estimate

Startup Operations Cost Estimate				
Item	Capital Cost	Set-up Fee	Monthly Cost	Per Run
Burner/Controls	\$86,000.00			
Propane Tank		\$150.00		
Generator			\$1,200.00	
Control Trailer		\$200.00	\$165.00	
Portable Toilet			\$100.00	
Propane & Fuel				\$241.00
Forklift (Large)			\$2000.00	
Insulation				\$454.00
Wire Materials				\$47.00
Thermocouple Replacement				\$185.00
Labor			\$15,840.00	
Totals		\$350.00	\$19,305.00	\$927.00
Monthly Cost		\$350.00	\$19,305.00	\$10,197.00
Total Monthly Cost			\$29,852.00	
Tons HGD/Month			165	
Cost Per Ton				\$181.00

After on-the-job training of operators and the transportable HGD system is tuned and optimized, higher production output is achievable. A full-scale production cost estimate for operation of the transportable HGD system is based on the following parameters:

- Operational costs incurred during demonstration tests
- Production rates projected and optimized from experience in demonstration tests
- The material quantities and associated costs shown in Table 6.1-8
- 22 runs per month – one every weekday
- 20 tons per run
- 2 operators/setup persons full time
- 1 run completed in 8- hour day.
- 1 setup completed in 8-hour day.

A breakdown of costs for full scale operations over the long term is presented in Table 6.1-10, which shows a processing cost of \$91 per ton (not including capital cost which is fully recoverable as a transportable system, and not including ambient air monitoring).

Table 6.1-10. Full-Scale Production Cost Estimate

Full-Scale Production Cost Estimate				
Item	Capital Cost	Set-up Fee	Monthly Cost	Per Run
Burner/Controls	\$86,000.00			
Propane Tank		\$150.00		
Generator			\$1,200.00	
Control Trailer		\$200.00	\$165.00	
Portable Toilet			\$135.00	
Propane & Fuel				\$241.00
Forklift (Large)			\$2000.00	
Insulation				\$454.00
Wire Materials				\$47.00
Thermocouple Replacement				\$185.00
Labor			\$15,840.00	
Totals		\$350.00	\$19,305.00	\$927.00
Monthly Cost		\$350.00	\$19,305.00	\$20,394.00
Total Monthly Cost			\$40,049.00	
Tons HGD/Month			440	
Cost Per Ton				\$91.00

6.2 COST COMPARISON

The cost for the transportable HGD system in a blanket-on-pile configuration was compared with two similar and comparable types of facilities for range scrap treatment that are currently available as follows:

- A permanent fixed-facility HGD as reported in "Demonstration Results of Hot Gas Decontamination for Explosives at Hawthorne Army Depot (Final)"⁹.
- A transportable HGD furnace as reported in "Validation Test Report for the Transportable Hot-Gas Decontamination System Used to Support the Decontamination of Explosives contaminated Piping and Debris"¹².

A head-to-head comparison of the cost for the blanket-on-pile transportable HGD system was made versus the fixed facility using an HGD furnace and the transportable HGD furnace in this section. Refer to Section 5.7 for a comparison of the technical components of the three technologies.

The fixed facility and the transportable HGD furnace cost comparison data was based on the following parameters:

1. 15,000 tons of scrap was decontaminated.
2. A 5 day, 8-hour per day work week with 20 to 22 work days per month for the fixed facility and for the blanket-on-pile transportable HGD system.
3. A 7 day, 24-hour per day work week for the transportable HGD furnace.

A line-by-line comparison of the three types of HGD facilities is presented in Table 6.2-1.

The transportable blanket-on-pile configuration is simple and inexpensive for capital cost compared to the permanent fixed HGD facility which includes a permanent building and

FINAL

infrastructure, and requires substantial environmental permitting. The transportable blanket-on-pile system has no emissions point source and no off-gas treatment system, and consequently is cheaper to operate and maintain for this equipment. At \$97 per ton, transportable blanket-on-pile system is less expensive on a per ton basis than the fixed facility HGD furnace at \$424 per ton, mostly due to the capital cost of the fixed facility.

When compared to the transportable HGD furnace, the blanket-on-pile configuration has considerably higher production rate and is operated one shift, five days per week. The disadvantages of the transportable HGD furnace are its small capacity per load cycle (at 1.5 tons per load cycle), and the need to operate 24 hours per day seven days per week to achieve reasonable production rate. This results in more expensive operating cost for the transportable HGD furnace for labor costs 24 hours per day, 7 days per week. Again, the transportable blanket-pile system has no emissions point source and no off-gas treatment system, and consequently is cheaper to operate and maintain in this area. At \$97 per ton, transportable blanket-on-pile system is less expensive on a per ton basis than the transportable HGD furnace at \$1061 per ton, mostly due to the operating labor cost and time required to treat for the HGD furnace.

Table 6.2-1. Technology Comparison - 15,000 Ton Site Cost Comparison

	Thermal Blanket	Fixed Facility	Transportable Furnace
Total Tons to Treat	15,000	15,000	15,000
Tons Treated / Day	20 ^a	16.4 ^b	6 ^c
Work Days/Month	22	22	22
Tons Treated / Month	20*22=440	16.4*22= 360.8	6*22=132
Tons Treated / Year	440*12 = 5,280	360.8*12=4,329.6	132*12=1,584
Treatment Cost /Ton	\$93.00 ^d	\$78.00 ^b	\$1,031.00 ^c
Capital Equipment Cost	\$86,000.00	\$5,194,000.00	\$690,000.00
Total Treatment Time	2.9 years	2.5 years	6.9 years
Capital Cost/Ton	86,000/15,000= \$5.73 or \$6.00	5,194,000/15,000= \$346.27 or \$346.00	690,000/15,000= \$46.00
Total Cost/Ton	93.00+6.00= \$99.00	78.00+346.00= \$424.00	1,031.00+46.00= \$1,077.00
Treatment Cost/Day	99.00*20= \$1,860.00	424.00*16.4= \$6,953.60	1,077.00*6= \$6,462.00
Treatment Cost/Month	\$1,860.00*22= \$40,920.00	\$6,953.60*22= \$152,979.20	\$6,462.00*22= \$142,164.00
Treatment Cost/Year	\$40,920.00*12= \$491,040.00	\$152,979.20*12= \$1,835,750.40	\$142,164.00*12= \$1,705,968.00
Total Cost for 15,000 Tons	\$491,040.00*2.9= \$1,424,016.00	\$1,835,750.40*2.5= \$4,589,376.00	\$1,705,968.00*6.9= \$11,771,179.20

^a Value based on testing performed during this demonstration.

^b Values from a permanent fixed-facility HGD demonstration as reported in "Demonstration Results of Hot Gas Decontamination for Explosives at Hawthorne Army Depot (Final)" (ref 15).

^c Values from a transportable HGD furnace demonstration as reported in "Validation Test Report for the Transportable Hot-Gas Decontamination System Used to Support the Decontamination of Explosives contaminated Piping and Debris" (ref 16).

^d Value from Table 5.1-7. Full Production Cost Estimate minus the capital cost (\$99.00- 6.00).

FINAL

7.0 Regulatory Issues

Federal, state, local and Army regulations were applicable in the developmental stages of the HGD demonstration and will apply in its implementation. These regulations include federal laws such as the Resource Conservation and Recovery Act (RCRA), the Military Munitions Rule (MMR), the Clean Air Act, and other local and Army regulations. A summary of each regulation's impact on HGD is as follows:

RCRA and Military Munitions Rule: The range scrap used in this demonstration was gathered from ATC ranges. Scrap generated during training and testing on the range are defined as range residue and must be managed in accordance with DoD 4160.21-M³¹, Chapter 4. The range residue at ATC is exempt from solid waste disposal regulations due to being recycled. Some of these items were found to contain surface contamination with trace quantities of explosive residue and assumed to be non-reactive thus, were ideal to use as test items for the HGD demonstration. Therefore, in this particular case, HGD should not constitute hazardous waste treatment. Range residue used in this demonstration include expended and demilitarized 155mm rounds, target plates, I-beams cut with explosive compounds, and armor used in proof testing.

Some of the above items are addressed by the Military Munitions Rule (EPA Munitions Rule) published in 1997. The EPA Munitions Rule is codified at 40 CFR Parts 260 through 266 and Part 270. Section 266.202 states that military munitions are not a solid waste when used in military training exercises, weapons testing, and range clearance operations. Munition items used in this demonstration resulted from these actions and are not classified as a solid waste according to the Military Munitions Rule under RCRA.

The thermal blankets were sampled for HCLP explosives and TCLP metals. No presence of any compounds on the 8095 analyte list was detected. TCLP metals were analyzed according to EPA method 1311 and all metals were under the reporting limit. Therefore, the thermal blankets sampled do not fall under the RCRA classification for hazardous waste.

Clean Air Act: The HGD demonstration was initially coordinated through the Maryland Department of the Environment (MDE) with a Determination of Coverage Letter providing an exemption from the existing Title V air permit. By the time the actual testing of the system occurred, MDE agreed that this activity could be covered under the county open burn permit for testing purposes only. This was based on the fact that HGD system was transportable and a non-point source emitter.

Because there was no point source of emissions, the fugitive emissions were monitored and the results were submitted to MDE for evaluation and advisement. This will greatly affect the usability of HGD in the state of Maryland, and set precedence for other DoD installations and future possible applications in all related arenas. This information is still forthcoming from MDE at the time of publication of this report.

7.1 APPROACH TO REGULATORY AND END-USER ACCEPTANCE

HGD is a possible solution to various disposal issues with respect to range residue. In this demonstration, transportable HGD uses are shown with respect to items containing surface contamination with trace quantities of explosives. Although many of these items fall under the MMR and are not classified as a solid waste under RCRA, they still pose environmental and safety risks. By utilizing transportable HGD on the range, these risks

FINAL

remain on the range and lessen environmental impacts. HGD is also more readily usable because of its exemptions from air permitting, provided that the state in which it is utilized allows a determination of coverage due to the reasons previously stated.

NEPA and Army Regulations require environmental documentation for all federal actions (e.g., military training, testing, and construction projects). HGD documentation consisted of a Record of Environmental Consideration (REC) and the previously discussed determination of coverage letter (pending from MDE). The REC only identified the possibility of airborne vapors, which as already been addressed in this section, and the usage of utilities.

In analyzing the results of this demonstration, the most prominent regulatory issues associated with the implementation of transportable HGD are (1) air emissions and (2) the degree to which the items are decontaminated under RCRA and MMR. In the implementation of transportable HGD, these issues are site-specific. The air emissions data presented in this demonstration pertain only to the fugitive emissions monitored from the demonstration test and has been evaluated with recommendations by the MDE in accordance to MDE and EPA regulations. Monitoring of site-specific representative composite samples of range scrap during test runs at future sites will be needed to provide data for that individual site, depending on the individual site's federal, state, and local regulatory requirements. Each individual site must also determine the degree of decontamination needed. This will also be site-specific depending on the items requiring decontamination and regulatory requirements.

8.0 Technology Implementation

8.1 DOD NEEDS

The disposal of range residue has recently been a matter of heightened interest among Congress and DoD officials. Each year, the Services expend more than 200,000 tons of munitions. In the Department of Defense Office of the Inspector General (DoD IG) Audit, "Review of Policies and Procedures Guiding the Cleanup of Ordnance on DoD Lands,"³ November 22, 1994, DoD IG reported that expended ordnance and explosive waste cleanup requirements and guidance developed by DoD and the Military Departments were incomplete, vague, and inconsistent.

Three years later, the Office of the Secretary of Defense requested the Inspector General, DoD, to evaluate the munitions disposal process after a commercial scrap worker was killed by a live anti-tank munitions shell. DoD IG responded with a separate audit entitled "Evaluation of the Disposal of Munitions Items"⁴ (Report No. 97-213, September 5, 1997). The primary objective was to determine whether DoD procedures and controls adequately ensured the safe disposal of ammunition, explosives, and other dangerous articles (AEDA) residue. The audit specifically evaluated the adequacy of the policies, procedures, and management controls associated with the disposal of DoD managed munitions. The audit report contained 25 separate recommended actions and concluded that the DoD needs to improve management controls to prevent public access to live AEDA. Specifically, DoD controls for the disposal of AEDA residue by the Military Departments were ineffective. As a result, the public was sold or had access to either discarded live AEDA or AEDA residue that had not been properly certified as inert.

Management controls at the Defense Reutilization Marketing Service to prevent the sale of live AEDA to the public were not fully effective. As a consequence, Defense Reutilization and Marketing Offices received and sold uncertified and improperly certified and stored AEDA residue to the public. DoD policies and procedures for AEDA disposal contracts, Direct Sales Programs as part of the Qualified Recycling Programs, reporting and investigating AEDA incidents, and demilitarization were inadequate. As a result, AEDA disposal service and sales contracts varied by installations and included disparate levels of safety and oversight.

A follow-up audit, "Disposal of Range Residue"⁵ (Report No. D-2000-170 August 4, 2000), revisited the status on the recommended actions of the 1997 audit report by reviewing current operations at eight military installations and their servicing Defense Reutilization and Marketing Offices. To address recommendations in Report No. 97-213, the Under Secretary of Defense for Acquisition, Technology, and Logistics convened a review team. A draft report contained recommendations to improve the disposal process, but did not contain standard DoD-wide guidance for managing the disposal of range residue, as recommended in the 1997 report. In early FY 2000, the Under Secretary directed a far-reaching and comprehensive review of munitions by the Operational and Environmental Executive Steering Committee for Munitions. The objective was to determine whether the Services were disposing range residue in a safe manner. Specifically, the adequacy of the policies, procedures, and management controls associated with the disposal of range residue generated on DoD terrestrial firing ranges. DoD IG recommended that the Under Secretary of Defense for Acquisition, Technology, and Logistics have the Operational and Environmental Executive Steering Committee for Munitions address the policy and procedural weaknesses and develop implementing guidance. As a result of the findings of the DoD IG audit, the Office of Deputy Under-Secretary of Defense for Infrastructure

FINAL

and Environment is preparing an instruction for handling and disposition of Material that Presents a Potential for Explosives Hazards (MPPEH).

This project directly addresses several Environmental Quality DoD requirements defined by the DoD Environmental Technology Requirements Strategy (1997)³² as follows:

1. United States Army Environmental Safety and Occupational Health (ESOH) Needs
 - ID - A(3.3a) Alternatives to Open Burning/Open Detonation
 - ID - A(4.3.b) Safety Issues
2. United States Navy Environmental Safety and Occupational Health Needs
 - ID - (1.I.4.e) Improved methods for removal of unexploded ordnance
 - ID - (2.III.1.t) Alternative ordnance disposal
 - ID - (3.I.13.a) Reuse/recycle of hazardous/polluting materials
3. United States Air Force Environmental Safety and Occupational Health Needs
 - Air Force Development and Testing Center
 - ID 1704 Reclamation/Recycling/Disposal of Munitions
4. United States Air Force Environmental Safety and Occupational Health Emerging Issues
 - ID 15 Military Munitions Rule (MMR) Compliance

The transportable HGD technology is particularly useful as an immediate solution for range residue and Open Burn/Open Detonation (OB/OD) residue at Base Realignment and Closure (BRAC) sites and Formerly Used Defense Sites (FUDS). There is great incentive for cleanup of BRAC sites, some of which are from BRAC rounds in 1988, and 1993 and 1995. These sites (especially from older BRAC rounds) must be cleaned up and removed from the BRAC list prior to the next BRAC round in 2005. Also, there is incentive to develop BRAC and FUDS by private developers amplifying the need for a low cost, transportable method for decontamination. Range residue and OB/OD residue are the last vestige resulting from the cleanup which must be addressed prior to regulatory acceptance of closure and finding of No Further Action.

Range sustainability of active and inactive military ranges has recently come to the forefront. Since no new ranges are foreseeable in the future, the long-term viability and continued availability of existing facilities, including test and training ranges, is critical for continued readiness. Department of Defense Directive Number 4715.11, "Environmental and Explosives Safety Management on Department of Defense Active and Inactive Ranges Within the United States"³³ establishes policy for sustainable use and management of DoD's active and inactive ranges within the United States, and for the protection of DoD personnel and the public from explosives hazards on active and inactive ranges. The objective is to ensure the long-term viability of DoD ranges while protecting human health and the environment. DoD Directive 4715.11 establishes policy for design and use of DoD ranges and the munitions used on them, in order to limit the potential for explosives mishaps and damaging effects to personnel, operational capability, property, and to promote resource recovery and recycling. Also, Executive Order 13123³³ requires the Secretary of Defense to develop and issue sustainable design and development principles. The transportable HGD process can become part of the sustainability

FINAL

solution for range maintenance at active and inactive ranges, by allowing range managers to remove and recycle range residue and OB/OD residue instead of storing it indefinitely.

8.2 TRANSITION PLAN

8.2.1 User Information Campaign

A substantial public information campaign has been undertaken that includes technical papers and presentations by the project team at many national technical conferences as follows:

“Low Cost Decontamination of Firing Range Scrap”, National Defense Industrial Association's Global Demilitarization Conference and Exhibition, (Sisk, Kelso, and Bright) Tulsa OK, May 19, 1999.

“Decontamination of Explosives-Contamination for Safe Recycling of Range Residue”, (Kelso) Joint Service Pollution Prevention/Hazardous Waste Management Conference, San Antonio TX, December 8, 1999.

“Low Cost Decontamination of Range Residue from UXO Sites”, The Department of Defense UXO/Countermines Forum, (Kelso, Cox, and Furnari) Anaheim CA, May 5, 2000.

“Low Cost Hot Gas Decontamination of Explosives-Contaminated Firing Range Scrap”, Joint EPA/DoD/DOE Strategic Environmental Research and Development Program, Partners in Environmental Technology Symposium and Workshop, Poster Session (Furnari, Sisk, and Kelso) Arlington VA, November 28 -30, 2000.

“Decontamination of Explosives-Contaminated Range Scrap Using Transportable Hot Gas Decontamination”, DoD's UXO/Countermines Forum, (Kelso and Furnari) New Orleans LA, April 10, 2001.

“Testing Underway for Hot Gas Decontamination of Explosive-Contaminated Range Scrap”, SERDP/ESTCP Partners in Environmental Technology Symposium and Workshop, Poster Session (Jack, Kelso, Sisk, and Furnari), Washington DC, November 27 – 29, 2001.

“Transportable Demilitarization System for Range Scrap” (Furnari, Jack, Kelso, and Sisk), The UXO/Countermines Forum, Orlando FL, September 3-6, 2002.

“Transportable Demilitarization System for and Range Residue and OB/OD Residue” (Kelso), HQDA BRACO, The Pentagon, Washington DC, October 28, 2002.

The presentations and papers have generated an extraordinary amount of interest from the DoD community. For example, more than one hundred military personnel and contractors attended presentations at two of the above conferences; the Global Demilitarization conference in Tulsa (1999) and the UXO/Countermines Forum in New Orleans (2001). Numerous range managers and cleanup managers attending these conferences have expressed an interest in implementing the technology at their installation, and are enthusiastic to see performance results.

In addition, the Headquarters Department of the Army BRAC Office (HQDA BRACO) has expressed interest in implementing the technology on OB/OD residues and range scrap, addressing long-standing problems at BRAC 1988, 1993, and 1995 sites. The HQDA BRACO invited the project team to give a briefing on the possible applications at BRAC sites. Parsons and ATC represented the project team to present the briefing on 28 October 2002. The BRACO requested additional information (contained in this report), to determine a path forward for possible applications at multiple BRAC sites.

FINAL

The DoD members of the development team will provide the final report and briefings to end users (e.g. DoD Range Commander's Council Environmental Group, the U. S. Army Corps of Engineers, the Joint Ordnance Commanders Group, and the Operational and Environmental Executive Steering Committee for Munitions) concerning efficacy and implementation of the technology.

An Implementation Guidance Manual¹⁸ has been prepared to assist installation personnel in determining the applicability and effectiveness of the HGD technology at their site. The manual provides sufficient information to move directly into procurement, installation, and operation of a HGD system for firing range scrap. A "How-to" videotape of the process was prepared by ATC and shows the step-by-step process with a voice-over narrative for decontaminating range residue by HGD. The video is a companion to the Implementation Guidance Manual that is an instruction tool to assist installation personnel in implementing the process.

Environmental regulatory officials from the EPA Environmental Technology Verification Program and Superfund Innovative Technology Evaluation program, as well as State and Regional environmental regulatory officials, are provided with copies of the final report.

8.2.2 Summary of Potential System Improvements and Opportunities for Future Testing and Development

The primary improvements to the Transportable HGD system based on performance and lessons learned during the field demonstration (see Section 7 and Section 9 for more detail) are summarized below.

A complete transportable demilitarization system would address all of the administrative and technical requirements necessary to prepare range scrap for commercial recyclers including:

- Inspection and certification;
- Decontamination;
- Demilitarization (rendered unfit for intended use or rendered unrecognizable); and
- Security.

The Transportable Hot Gas Decontamination addresses one of these requirements and by itself does not completely prepare the scrap for recycling in terms of inspection, certification, demilitarization and security. These requirements would be addressed in a semi-automated transportable processing system that minimizes manual labor and handling of the scrap, and one-by-one processing of the range scrap. This concept is address further below.

The issue of scrap security must be addressed to eliminate the opportunity for mixing in live rounds (prior to HGD) or mixing in untreated scrap to the pile after HGD; either on an active range during maintenance or during a range cleanup at a closed or inactive range. A HGD concept has been developed where the scrap would be decontaminated inside lockable wire basket containers or lockable dumpsters.

There are new insulation products recently on the market and under development that address health and safety issues for workers handling and installing the products. Testing of these products for ease of handling, durability, and thermal performance is recommended.

The processing speed and overall HGD system performance could be improved by several possible avenues including:

FINAL

- Use of two (possibly smaller) burners instead of one for better distribution of heat. The concept design seriously considered use of two (smaller) burners and had been proposed as such. However, for simplicity and cost savings, the system was design and procured with a single (larger) burner.
- Use of a hot air distribution manifold under (or around) the pile (described above),
- Reduce the size of the pile.

A heat distribution manifold from the burner (either underneath or external around the pile) would enhance heat up performance and processing rate, reduce processing time and labor cost, and reduce temperature damage to the insulation system.

The project team is actively pursuing funding for testing of these improvements. The fact that the test facility and infrastructure is already constructed and test-ready as a result of this project will mitigate the expense of follow-on testing.

8.2.3 Complete Transportable Demilitarization System

In the course of the demonstration, it was recognized that the transportable HGD system did not meet all of the administrative, safety, and other requirements for removal and recycling of the scrap metal. There are several other steps in addition to decontamination are required to prepare the scrap for recycling, and that were not addressed in the HGD demonstration. The Transportable Demilitarization System would rely on hoppers and conveyors for material handling to minimize manual handling of scrap between treatment modules.

The range scrap metal must be inspected and certified as free from AEDA prior to release to the public (commercial recyclers). Inspection, removal of items not acceptable for recycling, and certification would be performed on a slow-moving conveyor with a stop push button.

Security of the scrap is critical after the scrap has been certified as inert or after it has been decontaminated. The scrap must be locked and tightly controlled in lockable containers (preferred) or inside a locked fenced area, to prevent live items or uncertified items being inadvertently thrown on the pile after it has been inspected and certified, or decontaminated. There have been incidents where live items or AEDA have been placed in scrap that has previously been certified as free from AEDA. As a result, the scrap must be secured after it has been certified (or thermally treated).

In accordance with the Directorate of Logistics Defense Material Reutilization Manual³⁴, munitions items must be rendered unfit for its intended use prior to release to the public (i.e. commercial recyclers). This is a traditionally time-consuming and labor intensive operation by such means as drilling, punching, crimping, or shearing. A more recent interpretation of this requirement (post 9/11), is that munitions items must be rendered unrecognizable prior to release to recyclers. This results in reducing munitions to 4 or 6 inch size chunks using a shredder or low-speed high-torque shear.

A transportable demilitarization system will prepare AEDA, MPPEH, and range residue items for recycle according to DoD regulations. This transportable system will include:

- A electromagnetic magnetic crane for moving articles;
- An inspection/certification station mounted on a conveyor;

FINAL

A decontamination system (a transportable propane burner system fitted to a armored enclosure);

Followed by a demilitarization system (a scrap metal shredder).

The system will decontaminate, demilitarize, and certify mixed range scrap that includes an assortment of AEDA and MPPEH items, and prepare them for recycling at commercial recyclers.

The Transportable Demilitarization System will improve on the current status quo for range scrap handling in the following innovative ways:

1. Low cost implementation utilizing commercially available items, simple operation of the system, reusable components in the process, and minimal labor in operating the system.
2. In-place demilitarization of AEDA and MPPEH items will provide a practical, effective method of rendering these items safe and ensuring DoD compliance on the range.
3. Safety in the handling of these items will be assured due to the utilization of this process on the range. This is the most important new and innovative benefit of this technology. The processing system is remotely operated and controlled, and replaces labor-intensive and expensive torching cutting for demilitarization. It provides a uniform procedure to be followed by DoD personnel when processing these items for disposal, and quality control and quality assurance to ensure safety in the event of human error during the inspection process.

The proposed Transportable Demilitarization System would apply the above-described technologies in accordance with DoD guidance and policy to provide a failsafe method in the demilitarization of all items generated on the range.

9.0 Lessons Learned

9.1 GENERAL

The transportable HGD was proven effective decontaminating range scrap as designed. During the demonstration test, the system was proven and validated to process 14.5 tons in an 8-hour work day. An 8-hour work day is desirable for full scale production to save cost of premium overtime. The system was also proven capable of processing 20 tons in an 11-hour day. However, improvements to the production rate in tons treated per 8-hour day is desirable to reduce the overall cost. There are several possible avenues to improve performance and production up to 20 tons per 8-hour day or higher. These include:

- Oblong shape for pile along axis of burner, rather than circular piles that have difficulty distributing heat at 90° to the burner axis;
- Additional layers (more than one layer) of insulation;
- Use two opposing smaller burners; or
- Add a heat distribution manifold under, through, or around the scrap pile.

One way to lower cost of operations would be to operate unattended overnight, which may be safe and appropriate at certain installations where there is no fire hazard (such as a desert environment). The system is fully automated and designed for unattended operation (similar to a building heating system) to save labor cost. Fail safe and automated controls built into the control system would shutdown the system in the event of power loss or fuel supply interruption.

The seven demonstration tests were conducted during a very rainy period at Aberdeen Maryland. At the outset, the test area was so wet and muddy that a six-inch gravel bed was laid down just to work with personnel and equipment. During Test 1 through 4, the pile was drenched with water during startup, and steam was observed coming off the pile for one to two hours while the pile dried out. Heat up of the pile dramatically increased once the pile dried out. Test 7 was conducted in very heavy rainfall. The test took much longer to complete due to the rain. In general, it was observed that wet weather affects the time and cost to operate, but has no further deleterious effects on operations or equipment.

9.2 EQUIPMENT AND MATERIALS

9.2.1 Burner System

While the system worked as planned, increased production resulting in decreased cost is always a goal. A heat distribution manifold would greatly increase the process efficiency and decrease the processing time (and labor cost as well). The burner system would be much more effective with a heat distribution manifold at the outlet to direct the heat to the outer reaches of the pile. The heat distribution manifold would be a stainless steel duct starting at the burner shroud with a manifold running under (or around on the outside) and branch ducts feeding heat to the outer areas of the pile. This arrangement distributes heat evenly and quickly, thereby reducing heat-up time and operating cost, and solving other associated problems referenced above.

FINAL

Another approach to the same end would be two (smaller) burners, which would inject heat from opposite ends of the pile. During project planning, the multiple burner approach received serious consideration, but was not used to simplify the control system and reduce cost.

The hot air and heat from the burner tended to bounce off the pile where it impacted and deflected straight upwards. This was observed in the pile during Test 1, when the insulation slipped during installation creating a gap, and waves of heat were observed shooting upwards. As a result of the heat loss through the insulation gaps, the system did not effectively heat up the pile during Test 1.

The burner shroud was too short to prevent hot air deflecting off the pile. The end of the shroud was 6 or 8 feet short of the pile. A heat shield (sheet metal or half pipe) should be used to direct the heat into the pile to defeat the heat deflection phenomenon. The heat shield would be a piece of metal spanning from the end of the shroud to the pile. An I-beam was used in later tests to span from the top of the burner shroud horizontally to the pile. While only 10 or 12 inches wide, the purpose of the I-beam was to assist deflecting heat downward toward the pile.

The initial configuration of the pile and insulating system left the burner face plate unprotected from the heat bouncing back from the pile to the burner. This subjected the burner face plate to the high heat in earlier tests. Upon inspection, no damage was observed to the face plate metal, but the paint was burned off the face plate. The face plate was protected from the heat in later tests by placing insulation in front of the face plate.

In all tests, a large portion of the pile (possibly a third of the pile) experienced very high temperatures (up to 1800°F) and achieved 5X condition (1000°F for 15 minutes). This indicates that a smaller pile size can fully meet 5X condition with the existing burner/insulation system.

9.2.2 Control and Data Acquisition System

Thermocouples

The thermocouples were K-type thermocouples with a maximum temperature limitation of 1800°F. The thermocouple leads wires were rated at 1200°F maximum. In early tests, three thermocouples failed at approximately 1250°F, all at the hottest locations closest to the burner. It would appear that the lead wires were not sufficiently protected from the heat in these instances and too much lead wire was placed inside the insulation. In later tests, thermocouple leads were inserted through small penetration holes in the insulation and anchored to stainless steel wire mesh, thereby avoiding further thermocouple damage and failure. The insulation protected the lead wires, which were placed outside the insulation along their entire length.

9.2.3 Insulation Materials and Installation

The insulating materials tended to present a nuisance and potential health hazard during installation and removal. Both insulations (silica-based and fiberglass) required the use of personal protective equipment (PPE) for installers. The silica-based insulation gave off a fibrous dust when handling (both new and used i.e. exposed to high temperature). The Material Safety Data Sheets (MSDS) for the both the silica-based and fiberglass insulation indicate inhalation and skin contact hazards requiring appropriate PPE.

Unshrunk type SilMat by Ametek (silica-based high temperature insulation mat) should not be used under any circumstances. The unshrunk SilMat was too fragile for this application and extremely difficult to handle and install. The unshrunk SilMat ripped under its own weight when

FINAL

lifted and when tearing gave off a dust of silica fibers into the air. This in turn was a health hazard (respiratory and skin irritant) for installers as listed in the MSDS. Shrunk SilMat (which is pre-shrunk at the factory, consolidated, and has higher strength), and was far superior to Unshrunk SilMat for usability.

Discoloration of fiberglass insulation material when subjected to heat to a light brown color (slightly burned looking) was observed and is considered normal. The starch binder material (about 1 or 1.5 percent by weight) burns to this color. The 1-inch thick fiberglass insulation is heavy and had to be installed with a forklift, while the 1/2-inch thick fiberglass is much lighter and easier to handle.

The Siltemp high temperature fabric (welding blanket) appeared redundant to the high temperature insulation, particularly when its cost is considered. It was purchased to protect the insulation in very hot areas. However, it did not exhibit any special ability to do so, above the high temperature insulation inherent capability. The temperature limitation of the Siltemp was 1800°F, while the temperature limitation of the SilMat insulation was higher at 2000°F, thereby eliminating the need for the SilTemp. The SilTemp alone does not have enough mass or weight to hold in hot air alone without the insulation.

The thermal blankets are very heavy when wet, and cannot be moved in this condition. The blankets should be kept dry under tarps when not in use. The blankets can be dried out in place on the pile by the burner if they get wet in place on the pile (between operations and removal).

Installation of Insulation System

As expected, the burner hot air and heat tends to follow path of least resistance. Therefore, heat did not circulate to areas of the pile that do not get hot air circulation. Areas where the insulation blanket touched the ground tended to be cold (rather than hot as may be intrinsically be expected) because hot air would circumvent these areas and flow to nearby areas of the pile where the hot air could escape.

The burner system struggled to quickly meet temperature criteria in the outer reaches of the pile (lower areas left, right, and directly away from the burner). Trial and error during the test runs determined that a continuous uniform minor gap (1 or 2 inches) around the perimeter of the back half of the pile (along the ground away from the burner) seems to direct the heat most uniformly to the furthest reaches of the pile. Spot venting cause cold spots and hot spots where hot gas funneled to the vent and circumvented closed up areas. The left and right edges of the pile (at the ground at 90° from the burner in each direction) are the slowest to heat up to temperature, unless hot air is directed to these areas as described above.

Test 4 was the most successful test in terms of time (and therefore cost) achieving successful decontamination in approximately 7 hours (4 hours heat-up and 3 hours soak). An extra layer of insulation (1-1/2 to 2 inches total in many areas) was used in Test 4 which contributed to speeding up the heat-up process time. (Note that the Time-temperature criteria was lower than all tests in Test 4 (500°F for 2 hours), causing the decontamination process to fail in one area of the pile. Conversely, Test 6 or 7 used less insulation (1/2 inch in many places) and the heat-up took noticeably longer (thereby increasing operator labor cost). A 1/2 inch of insulation is not enough insulation to effectively heat-up the pile in a reasonable amount of time. A 1 1/2 to 2 inch layer is recommended to accelerate the process, increase processing rate, reduce labor cost and fuel consumption.

FINAL

As observed in Test 1, visible gaps (small or large) in the insulation system (the exhaust vent along the ground being the exception) result in significant heat loss and should be avoided. Due to the gap in the insulation, the pile was clearly losing a tremendous amount of heat through the gap. As a result, the maximum temperatures that the hottest thermocouples reached in test 1 were about 950 °F (and could have been much higher without the gap). Gaps in the insulation will result in failure to meet time-temperature performance criteria.

The insulation manufacturing industry has recognized the problems and health hazards associated with its current products, and is actively addressing this situation with new product development. Several new products are currently on the market or under development that show promise to mitigate or relieve the health hazards and need for PPE associated with handling of the insulation. Some examples include:

- Superwool – Thermal Ceramics (thermalceramics.com) – High temperature Calcium/magnesium/silica-based mat blanket good to 2012°F.
- Silcosoft™ - BGF Industries, Inc., Greensboro NC (bgf.com): High temperature silica-based mat blanket good to 2000°F. Manufacturer claims the product is non-dusting, non-irritating, and a 9-micron diameter fiber is non-respirable making handling safe and easy.
- Basalt Mat – BGF Industries, Greensboro NC (bgf.com): High temperature mineral wool (basalt fiber wool) mat blanket good to 1500°F. Product is still under development (2002) but shows promise.

9.2.4 Utilities

The failure of the electric power generator in Test #1 failed the entire test. The Lesson Learned here is that if reliable fixed line power is available at range site, it is preferable to a less reliable electric power generator.

9.3 SECURITY

Security of the scrap is a critical after the scrap has been certified as inert or after it has been decontaminated. There have been known incidents where live items or AEDA have been placed in scrap that has previously been certified as free from AEDA (or has been subject to low temperature thermal desorption). As result, the scrap must be secured after it has been certified (or thermally treated). The concern is that a live round or flashable item becomes inadvertently mixed into scrap that has already been inspected, certified, and decontaminated.

The fundamental concept of the Transportable HGD system in a pile configuration is to decontaminate a pre-existing pile of range scrap. However, the pile of scrap must be free from live rounds. Since a pile of scrap on a range is intrinsically not a secure configuration (even if inside an installation's fence and gate, since a live item from an on-site range cleanup can be placed on a pile). In fact, inspection and certification of scrap already in a pre-existing pile will most likely be required, unless the pile has been tightly secured and there is assurance that no live rounds have been added.

As a result of the above, Hot Gas decontamination in lockable containers (either lockable wire basket containers or lockable dumpsters) may have added value to address the security/certification issue.

FINAL

10. References

1. Parsons. *Design Guidance Manual for a Low Cost Disposable Hot Gas Decontamination System for Explosives-Contaminated Equipment and Facilities*. Report No. SFIM-AEC-ET-CR-98046, Denver, Colorado. November 1998.
2. United States Defense Environmental Restoration Program, *Final Record of Decision*, Umatilla Depot Activity Explosives Washout Plant Operable Unit, Umatilla OR, June 1994.
3. Department of Defense Inspector General. *Review of Policies and Procedures Guiding the Cleanup of Ordnance on DoD Lands*, Washington DC, November 22, 1994.
4. Department of Defense Inspector General. *Evaluation of the Disposal of Munitions Items*, Report No. 97-213, Washington DC, September 5, 1997.
5. Department of Defense Inspector General. *Disposal of Range Residue*, Report No. D-2000-170, Washington DC, August 4, 2000.
6. Battelle Columbus Division. *Pilot Plant Testing of the Hot Gas Building Decontamination Process*, U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), Report No. AMXTH-TE-CR-87130, October 1987.
7. Arthur D. Little, Inc. *Pilot Plant Testing of Caustic Spray HGD Building Decontamination Process; Task Order 5*, USATHAMA, Report No. AMXTH-TE-CR-87112, August 1987.
8. Roy F. Weston, Inc. *Task Order 2 - Pilot Test of Hot Gas Decontamination of Explosives Contaminated Equipment at Hawthorne Army Ammunition Plant, Hawthorne Nevada*, USATHAMA, Report No. CETHA-TE-CR-90036, July 1990.
9. The Tennessee Valley Authority Environmental Research Center, *Demonstration Results of Hot Gas Decontamination for Explosives at Hawthorne Army Depot (Final)*, Vol. I-IV, Hawthorne Nevada 89415-0015, USAEC, Aberdeen Proving Ground, Maryland, 21010-5401, September 1995.
10. Parsons Engineering Science, Inc., Battelle Pacific Northwest Laboratories, *Final Technical Report: Field Demonstration of the Hot Gas Decontamination System*, Report No. SFIM-AEC-ET-CR-95011, USAEC, Aberdeen Proving Ground, Maryland, February 1995.
11. Roy F. Weston, Inc., *Operations and Maintenance Manual for the Transportable Hot-Gas Decontamination System Used to Support the Decontamination of Explosives Contaminated Piping and Debris*, Vol. I-V, Contract No. DACA 31-91-D-0079, Task Order 12, USAEC, Aberdeen Proving Ground, Maryland, September 1996.

FINAL

12. Roy F. Weston, Inc., *Validation Test Report for the Transportable Hot-Gas Decontamination System Used to Support the Decontamination of Explosives contaminated Piping and Debris*, Vol. I-III, Contract No. DACA 31-91-D-0079, Task Order 12, USAEC, Aberdeen Proving Ground, Maryland, September 1996.
13. Arthur D. Little, Inc., *Final Feasibility Study for Explosives Washout Plant-Building 489 (OU6) at the Umatilla Depot Activity (UMDA)*, Rev. 0, DAAA15-91-D-0016, Delivery Order No. 2, United States Army Environmental Center (USAEC), Aberdeen Proving Ground, Maryland, December 1993.
14. United States Department of the Army, Department of the Army Technical Bulletin, *Decontamination of Facilities and Equipment*, TB 700-4, Washington D.C., October 1978.
15. Shipley, T. *Conducting Magnetometer Sweeps*. SOP 385-2384. 6 May, 1996.
16. Shipley, T. *Destruction and Dud Ammunition Located on Ground Surfaces*. SOP 285-2048. 31 May, 1997.
17. U.S.Army Aberdeen Test Center/Parsons. *Final Demonstration Plan, Low-Cost Decontamination of Explosives-Contaminated Range Scrap Using a Transportable Hot Gas Decontamination System*, Aberdeen MD, May 2001.
18. U.S.Army Aberdeen Test Center/Parsons. *Implementation Guidance Manual, Low-Cost Decontamination of Explosives-Contaminated Range Scrap Using a Transportable Hot Gas Decontamination System*, Aberdeen MD, November 2002.
19. U.S. Army Aberdeen Test Center. SOP 385-2389, *Planning the Disposition of Range Residue and Management of the Range Residue Consolidation Facility*, Aberdeen MD.
20. EPA, Compendium Method TO-14A, *Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using Specifically Prepared Canisters With Subsequent Analysis By Gas Chromatography*, January 1999.
21. EPA, Compendium Method TO-13A, *Determination of Polycyclic Aromatic Hydrocarbons (PAHs) in Ambient Air Using Gas Chromatography/Mass Spectrometry (GC/MS)*, January 1999.
22. USACHPPM, Directorate of Laboratory Sciences, *Chromatographic Analysis Division, Procedure for Analysis of Explosives in Air*, SOP CAD 26.2, November 2000.
23. Method D6209-98, *Standard Test Method for the Determination of Gaseous and Particulate Polycyclic Aromatic Hydrocarbons in Ambient Air (Collection on Sorbent-Backed Filters with Gas Chromatographic/Mass Spectrometric Analysis)*. American Society for Testing and Materials, July 1998.

FINAL

24. Title 40, CFR, 1993 rev, Part 50, Appendix B, *Reference Method for the Determination of Suspended Particulate Matter in the Atmosphere (High-Volume Method)*.
25. EPA, *Compendium of Methods for the Determination of Inorganic Compounds in Ambient Air, Sampling of Ambient Air for Total Suspended Particulate Matter (SPM) and PM10 Using High Volume (HV) Sampler, Method IO-2.1*, Office of Research and Development, Washington, DC June 1999.
26. Rupprecht & Patashnick Co., Inc., *Operating Manual, Partisol® -FRM Model 2000, PM-2.5 Air Sampler, Revision B*, Albany, NY, 12203, October 1998.
27. U.S. Army Center for Health Promotion and Preventive Medicine, *Ambient Air Quality Assessment No. 43-EL-6590-01*, Aberdeen Test Center, Aberdeen Proving Ground, Maryland, 10 August - 16 October 2001
28. American Conference of Governmental Industrial Hygienists, *Threshold Limit Values for Chemical Substances, Physical Agents, and Biological Exposure Indices*, 2001.
29. U.S.Army Aberdeen Test Center/Parsons. *Cost and Performance Report, Low-Cost Decontamination of Explosives-Contaminated Range Scrap Using a Transportable Hot Gas Decontamination System*, Aberdeen MD, November 2002.
30. RS Means, *Construction Cost Data*, Kinston MA, 2001.
31. Department of Defense Directorate of Logistics *Defense Material Reutilization Manual*, DoD 4160.21-M, Washington DC August 97.
32. Department of Defense. *Environmental Technology Requirements Strategy*, Washington DC (1997)
33. Department of Defense Directive Number 4715.11, *Environmental and Explosives Safety Management on Department of Defense Active and Inactive Ranges Within the United States*, Washington DC, August 17, 1999.
34. Office of the President, Executive Order 13123, *Greening of the Government Through Efficient Energy Management*, Washington DC, June 3, 1999.